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NAVAL APPLIED SCIENCE LAB BROOKLYN N Y  
OCEANOGRAPHIC SYSTEMS PROGRAM INVESTIGATION OF SOUND VELOCITY P--ETC(U)  
1965

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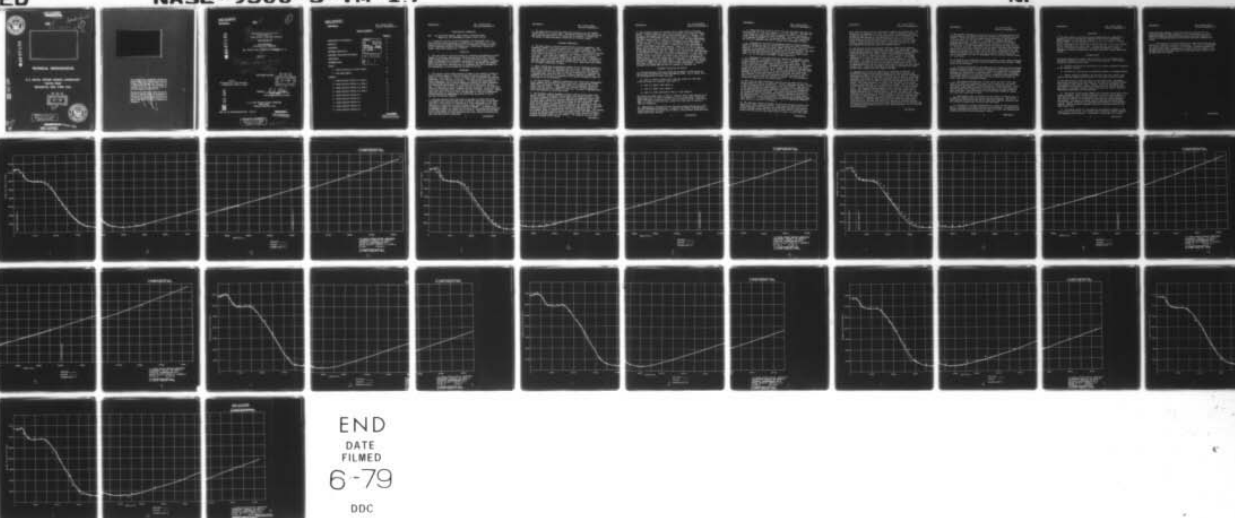
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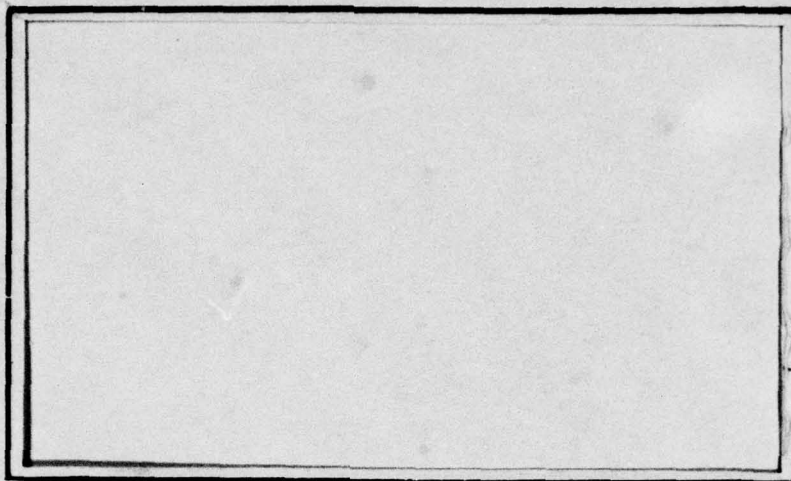
LEVEL II

*Sound velocimeter*

MOST PROJECT - 2

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*RF*



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## TECHNICAL MEMORANDUM

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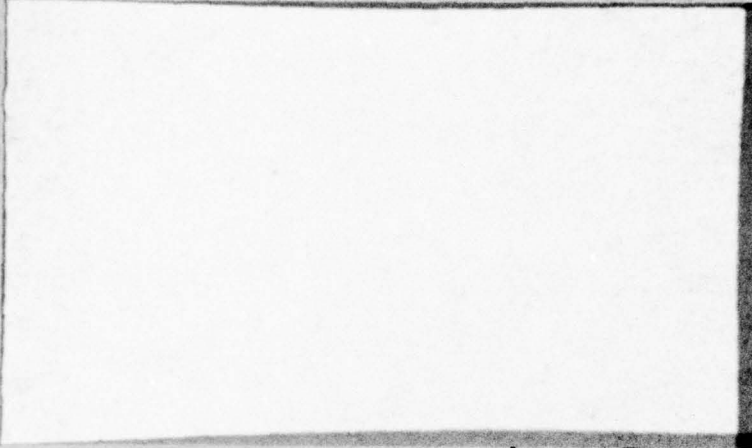
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LEVEL II

①

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⑥  
OCEANOGRAPHIC SYSTEMS PROGRAM  
INVESTIGATION OF  
SOUND VELOCITY PROFILING SYSTEM, (U)

MANUFACTURED BY

ACF ELECTRONICS  
DIVISION OF ACF INDUSTRIES

LAB. PROJECT 9500-5, TECHNICAL MEMORANDUM NO. 15

1965  
⑭ NASL-9500-5-TM-15

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#### ADMINISTRATIVE INFORMATION

Ref: (a) Instruction Manual, Sound Velocity Profiling System,  
Model SD-3, ACF Electronics Division; Parts I and II

1. As Technical Director of the Oceanographic Systems Program, the U. S. Naval Applied Science Laboratory is conducting an investigation of a Sound Velocity Profiling System manufactured by the Underwater Systems Laboratory of ACF Electronics Division; ACF Industries, 11 Park Place, Paramus, New Jersey, under Naval Contract No. SP 64177F.

#### OBJECTIVE

2. The Sound Velocity Profiling System is a shipboard instrumentation system capable of obtaining, processing and recording data describing a vertical sound velocity profile of the ocean. It is the objective of this investigation to determine the performance characteristics of the system, to compare these characteristics with those of the presently used Nansen cast method and to evaluate these characteristics in accordance with the requirements of the Oceanographic Systems Program and the needs of the Navy.

#### BACKGROUND

3. The Sonarray Survey System requires an input of the velocity of sound in water at various depths in order to perform ray-bending calculations. The method now in use employs a series of Nansen casts to determine the required parameters. This makes use of the fact that sound velocity is a function of water temperature, salinity and pressure. A protected and unprotected reversing thermometer pair provides temperature pressure and depth information; and conductivity measurements of a collected water sample gives salinity data. In operation, a series of Nansen bottles are attached to the hydrowire, lowered to the desired depth, triggered and then recovered. During this operation, which lasts about four hours, the ship must be dead-in-the-water. Several additional hours are required for an oceanographer to read the thermometers, perform conductivity measurements and analyze the data before it may be fed into the Sonarray Computer.

4. The Sound Velocity Profiling System is designed to reduce these time requirements while providing data with accuracy at least equal to the Nansen cast data. Sound velocity is obtained by a direct measurement of the time required for a sound wave to travel through a known length of water. Depth is measured by means of a pressure sensitive transducer. In operation, an instrumented cylinder is lowered into the water to the maximum depth permitted by the cable length, then raised back to the deck. Sound velocity and depth data are printed out in final form during this cast, thereby eliminating the post time data analysis requirement.

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5. The Sound Velocity Profiling System was installed on the USS COMPASS ISLAND (EAG153) on 7 January 1965. Preliminary evaluations were made during the at-sea test periods of 11-20 January and 23 February - 12 March 1965. The results of these preliminary evaluations are included herein.

#### EQUIPMENT DESCRIPTION

6. The Sound Velocity Profiling System consists of three assemblies: the transducer assembly, the winch assembly and the readout equipment. The transducer assembly is a stainless steel cylinder housing an ACF Model TR-4 Velocimeter and a Fairchild 3S-G Pressure Transducer. The velocimeter consists of two ceramic piezoelectric transducers and a reflector mounted in a fixed sound path. These sound path components, in conjunction with a blocking oscillator, form a ring-around circuit whose repetition rate is determined by the time required for sound to travel through the sound path. The pressure sensitive depth transducer employs a silicon strain gage bridge whose output is a DC signal proportional to depth.

7. Signal transmission and mechanical support for the transducer housing is provided by 12,000 feet of Amergraph Type 3-H-0 cable. The underwater end is electrically terminated in three Marsh and Marine Type MC-SL-F16S pressure proof connectors; the cable armor at this end is mechanically terminated in a stainless steel block from which the transducer housing is suspended. The shipboard end of the cable is connected to the readout equipment by means of slip-rings on the winch assembly.

8. The winch assembly, Commercial Engineering Corp. Series 1000 Oceanographic Hoist, consists of an electro-hydraulic power unit, a hydraulically driven winch and a retractable A frame. Cable payout is continuously variable to about 6 feet per second. A speedometer and odometer indicates payout and rewind rates and the total lengths of cable out. The winch is equipped with a level wind mechanism to facilitate rewind.

9. The electronic readout equipment includes a Hewlett-Packard Model 562A digital recorder, three Hewlett-Packard Model 5214L preset counters, a Vidar voltage-to-frequency converter, an ACF amplifier and frequency doubler unit, the input/control panel and a Harrison Laboratories Model 6207A power supply. The power supply provides the operating voltage for the transducers. The sound velocity signal is processed by the amplifier and frequency doubler unit while the voltage-to-frequency converter processes the depth signal. Processed signals are distributed to the proper counters by connections made at the input/control panel in accordance with the selected operating mode. The counters are presently preset to permit display of sound velocity and depth directly in units of feet per second and feet respectively; other units may be used by changing the preset numbers of the counters. The displayed data are simultaneously recorded by the printer.

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10. Three operating modes are available on the Sound Velocity Profiling System. In Mode A operation, with the units presently used (feet per second and feet), measurements are made and data recorded every 3.4 seconds. This corresponds to a measurement of sound velocity averaged over a depth of 17 feet when a payout rate of 5 feet per second is used; the depth measurement requires 1.1 seconds and is delayed to correspond to the center depth of the 17 foot interval. In Mode B operation, the sound velocity measurement interval is reduced to 0.34 seconds. Printout rate is then determined by the 1.1 second depth measurement interval. Mode C is the same as Mode B except that the sound velocity measurement is delayed so as to be centered in the depth measurement interval. Modes B and C provide finer granularity of information with more than three times as many printouts for the same depth; however, there is a reduction in accuracy and resolution. If other units are desired for the output data, the proper scale factors are inserted in the preset counters. For each change, the counting intervals and resolution of each operating mode must be re-evaluated. In general, if the sound velocity interval is larger than the depth interval, Mode A provides the best results while Mode C should be used if the depth interval predominates. Complete equipment description and operation is contained in reference (a).

#### EQUIPMENT EVALUATION AND RESULTS

11. The Sound Velocity Profiling System was evaluated in three series of casts during the operations of the USS COMPASS ISLAND. On 14 January 1965, the following series of casts were made:

- a. Cast 1-1, Mode A, Payout rate 3 feet per second for 0-600 feet, 5 feet per second for remainder [see Figure 1].
- b. Cast 1-2, Mode B (see Figure 2).
- c. Cast 1-3, Mode C (see Figure 3).
- d. Cast 1-4, Same conditions as Cast 1-1 (see Figure 4).

On 9 March two casts, Cast 2-1 and 2-2 (Figures 5 and 6) were made and on 10 March, Casts 3-1, 3-2 and 3-3 (Figures 7, 8, and 9) were made. These five casts were made at a payout rate of 5 feet per second with data recording in Mode A. On each of the three days, Nansen casts were made to provide a basis for comparison.

12. Mechanically, the Sound Velocity Profiling System performed well with a few minor operating difficulties. In general, the effects of these difficulties were minor; no serious loss of data or time occurred during the casts. These difficulties included:

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a. During the first series of casts, with the cable fully paid out, it was found that the winch was incapable of rewinding smoothly. The motor had to be brought up to full speed before engaging the clutch, thereby providing sufficient momentum to start the rewind. This was later attributed to an improper adjustment of the pressure relief valve. This trouble did not recur on subsequent casts and no further valve adjustment was made.

b. Occasionally, the level wind mechanism failed to operate properly, either by causing the cable to overlap the previous cable loop or by laying the cable too far from the previous loop, thereby leaving a gap. When this occurred, it was necessary to stop the winch, pay out the improperly laid cable length and then manually guide this length into its proper position. It seems possible that further adjustment of the level wind alignment might reduce (but not eliminate) the number of manual operations.

c. Vibrations in the winch power unit caused the "Stop-Reset" switch to trip repeatedly. The operator's control for the "Stop-Reset" switch is a spring-return button mounted on the control panel cover plate. This button is attached to a shaft which presses on the switch button. The length of this shaft is adjustable. Vibrations caused the locking nut to loosen so that the shaft occasionally hit the switch. The shaft was readjusted and locked and the problem did not recur. However, the design of the cover plate mounting was found to be poor. It is held in place by four screws; two connected to the power unit frame and two to the relay and switch chassis. Any vibrations in the frame are transmitted through this plate to the chassis causing the relays and switches to chatter. This was temporarily corrected by removing the two chassis screws.

13. One of the two depth transducers supplied with the Sound Velocity Profiling System was found to be defective. In-port examination in about 30 feet of water indicated a drift toward zero in the depth reading. When used in a cast, the transducer provided apparently inaccurate and intermittent data. It was replaced with the spare transducer and returned to the manufacturer for further examination and repair. The trouble was apparently caused by an intermittent internal connector and excessive temperature sensitivity in the amplifier module. While the second transducer did not exhibit either the intermittent or drift characteristic, its reading may be somewhat temperature sensitive. An investigation of the effects of temperature change on depth reading is presently in progress.

14. The watertight connectors between the cable and transducer housing were found to be a major source of trouble. Open connectors were found on two leads during the in-port checkout, an intermittent condition was traced to an open connector during the first series of casts and two connectors were found to be open prior to the second series of casts. In each case, there

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was a break in the wire at the point where it enters the connector pin. The connectors were repaired with a down time of about 30 minutes per failure. An improved connector and a protective housing to prevent recurrence of this failure has been designed by the manufacturer and will be installed and investigated as soon as fabrication requirements and ship's availability permit. Similar connectors were supplied at the output of the slip rings. As these connectors are contained within a watertight junction box, they were removed and replaced by taped and soldered splices.

15. The accuracy of the Sound Velocity Profiling System may be measured by the degree to which its data agree with Nansen cast information. Sound velocities obtained from a Nansen cast and three consecutive Sound Velocity Profiling System casts are shown in Table 1 and graphically presented in Figures 7, 8, and 9. Based on the data in Table 1, there is an average difference of 0.6 feet per second between the two methods. The maximum difference is 11.1 feet per second and the standard deviation is 3.1 feet per second. It should be noted that the casts were made over a period of ten hours during which the ship was drifting at speeds up to 4 knots. It is therefore possible that the actual sound velocity profile may have changed between casts. Additional experiments are planned to determine the extent to which this variation may have affected the data.

16. Repeatability of data was determined by comparison of profiles. To minimize the effects of any possible change in the actual profile, this comparison was based on the differences between the two profiles obtained on the descent and ascent of each cast. Using the data in Table 1, an average difference of 0.8 feet per second between the profiles was determined. The standard deviation was 2.4 feet per second and the maximum was 6.9 feet per second. The closest agreement was found in the deep half of the profile. At depths below 5,000 feet, it is reasonable to assume that the actual profile is constant and that any variance in data is due to a lack of repeatability. The average difference between the two profiles of each cast for depths below 5,000 feet was determined to be 0.2 feet per second with a standard deviation of 0.2 feet per second. However, for depths less than 5,000 feet, the variations are greater (average 1.1 feet per second, standard deviation 2.9 feet per second). Close analysis of the data indicates that the difference is greatest in regions of greatest change in sound velocity with depth (e.g. 1200-3000 feet in Figure 7) and almost disappears where sound velocity is constant with depth (750-1200 feet in the same profile). This can be caused by an error in the depth reading which may be partially due to temperature stabilization effects on the depth transducer; this is presently being investigated.

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17. The greatest advantage to be gained by the use of the Sound Velocity Profiling System is the reduction of the time required for measurement and data analysis. During the time the sound velocity transducer or the hydrowire is in the water, the ship must be at a standstill, thereby precluding Sonarray operations. In addition, during the time required for on-board measurements and data analysis, Sonarray must continue to use data from a previous cast. The time requirements for the two methods are shown in Table 2. It may be seen that a reduction of 85% in dead-in-the-water time resulted from the use of the Sound Velocity Profiling System. Data analysis for the Nansen cast required 2 to 4 hours; this time loss is eliminated in the Sound Velocity Profiling System as the data are available in final form at the time of measurement and could be programmed into the Sonarray computer during the rewind time.

18. In addition to the reduction in time requirements, several other advantages of the Sound Velocity Profiling System over Nansen casts were observed. Among these are the following:

a. The use of messengers in the Nansen cast to trigger the bottle tripping mechanisms presented some operational problems which are obviated by the Sound Velocity Profiling System. In one cast, seaweed was trapped by the descending messenger and cushioned the triggering impact. In another cast, a messenger wire became hooked on its bottle and failed to trigger the remaining bottles. A third cast failed to trip apparently because an excessively large wire angle slowed the the messenger's descent.

b. The dynamic characteristics of cable payout and ship's drift were found to be such that significantly more wire is required for the Nansen cast to reach the same depth as the Sound Velocity Profiling System. It was found that a cable angle of about  $60^\circ$  occurred with a four knot drift rate and that 16,000 feet of Nansen wire had to be paid out to reach a depth of about 9,000 feet. The Sound Velocity Profiling System reached this depth with less than 12,000 feet of cable.

c. When trouble (such as a failure to trip) occurs in a Nansen cast, it is often not apparent until the bottles have been recovered. Any loss of Sound Velocity Profiling System data is immediately apparent during the cast and corrective measures may be started with less delay.

d. The need for a trained oceanographer to conduct the cast and analyze data is eliminated by the Sound Velocity Profiling System. In addition, the hazards associated with working over the side of the ship while attaching and removing the Nansen bottles are greatly reduced.

## CONCLUSIONS

19. The Sound Velocity Profiling System has demonstrated its capability to adequately provide sound velocity profiles for use in the Oceanographic Survey Program. The limited data obtained at this time indicate that the profiles have an accuracy comparable to Nansen data and within the 3 ft/sec accuracy requirements of Sonarray ray bending corrections. Significant reduction of time requirements have been found. The equipment has demonstrated its ability to withstand the effects of a shipboard environment, including extremes in vibration, temperature, salt spray and shock, without significant failure.

## RECOMMENDATIONS

20. Several weaknesses in design have been found. It is recommended that appropriate measures be taken to correct these deficiencies. The following corrective actions should be taken:

- a. Complete fabrication and installation of improved waterproof connectors on the transducer housing.
- b. Continue the investigation of temperature effects on the depth reading.
- c. Improve mounting arrangement for the winch power unit control cover plate to prevent transmission of vibration to the relay and switch chassis.

21. The Sound Velocity Profiling System, as described herein, represents a significant improvement over the Nansen cast as a means of providing Sonarray with necessary sound velocity data. However, additional developments and improvements are desirable to further decrease lost time, improve the form and quality of the data, increase system reliability and simplify operation. Among these improvements are the following:

- a. The present system employs commercially available counter units in the readout equipment. These are multi-function devices which are capable of a wide range of counting and timing operations. As only a single function is used for each counter, it is possible to eliminate many unused components and controls. The removal of unused controls would provide simpler operation and increase reliability by precluding the possibility of an incorrect setting. Removal of unused components would also increase reliability and might reduce costs.
- b. The present method for disconnecting the transducer assembly to the cable involves the removal of two cotter pins, unscrewing a ground conductor and unplugging three connectors. Replacement of these parts by a single

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quick-disconnect connector, which would provide mechanical support, electrical connection and protection for the cable termination, would reduce the number of manual operations required and would increase reliability by eliminating parts, including the unreliable connectors now in use.

c. The possibility of further reduction of time during which the ship must be at a standstill should be investigated. This could be accomplished by increasing the rate of descent to the terminal velocity by permitting the unit to fall freely (estimated to be about 15 feet per second). It is estimated that an additional reduction in operating time of about 25% may be realized by this method.

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TABLE 1

SOUND VELOCITIES AT VARIOUS DEPTHS

DEPTH (FT.)	SOUND VELOCITY (FT./SEC.)						
	NANSEN CAST	SOUND VELOCITY PROFILING SYSTEM CASTS					
		3-1 DOWN	3-1 UP	3-2 DOWN	3-2 UP	3-3 DOWN	3-3 UP
154	5014.9	5013.1	5013.9	5016.7	5013.7	5013.3	5013.6
322	5014.9	5014.1	5014.8	5014.8	5015.6	5015.4	5016.0
446	5006.0	5009.7	5006.0	5010.1	5011.5	5016.4	5015.7
699	4996.7	4996.4	4996.2	4996.7	4996.9	4996.6	4996.6
961	4996.0	4995.1	4995.1	4995.1	4994.7	4994.5	4994.9
1234	4996.4	4995.6	4994.9	4995.3	4995.2	4996.2	4995.9
1463	4993.2	4990.0	4989.6	4992.3	4991.0	4995.7	4993.5
1801	4971.7	4975.2	4974.4	4978.0	4976.1	4980.0	4979.1
2159	4955.4	4950.5	4951.5	4958.7	4955.6	4956.3	4955.0
2536	4928.0	4923.9	4917.0	4929.0	4925.5	4932.5	4927.0
2703	4920.8	4912.5	4909.7	4917.0	4918.0	4919.0	4913.9
2976	4900.1	4899.7	4899.8	4904.7	4902.5	4903.0	4899.9
3527	4892.3	4890.1	4890.5	4892.4	4889.5	4893.4	4892.7
4554	4895.3	4892.3	4893.2	4894.2	4894.1	4893.6	4893.7
5636	4905.8	4903.8	4903.5	4904.4	4904.6	4903.7	4905.1
6768	4919.3	4918.4	4918.7	4918.8	4918.9	4919.3	4919.3
7926	4934.9	4934.1	4934.3	4934.4	4934.4	4935.1	4934.9
9186	4953.0	4951.3	4951.4	4951.5	4951.5	4952.7	4952.5

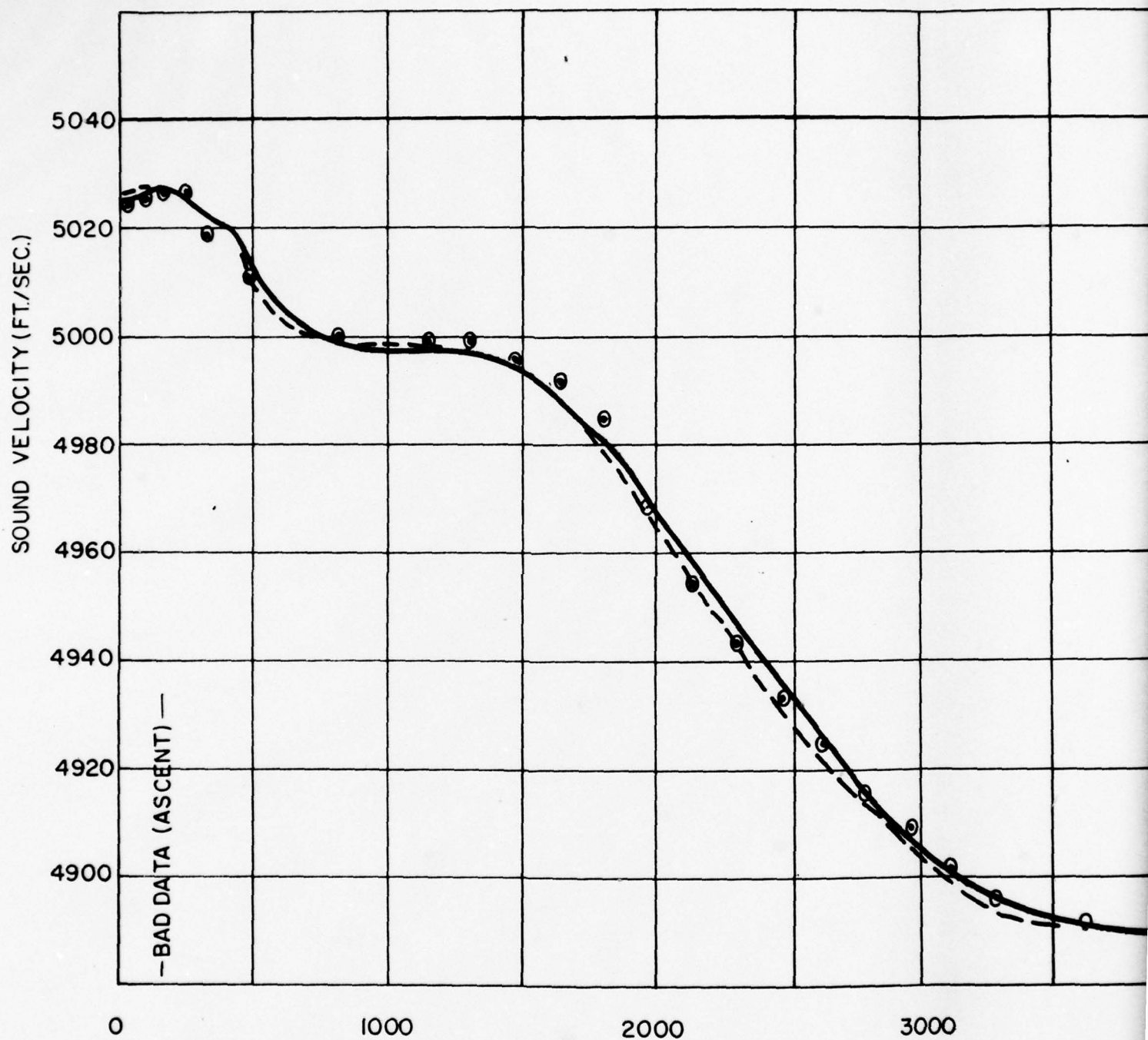
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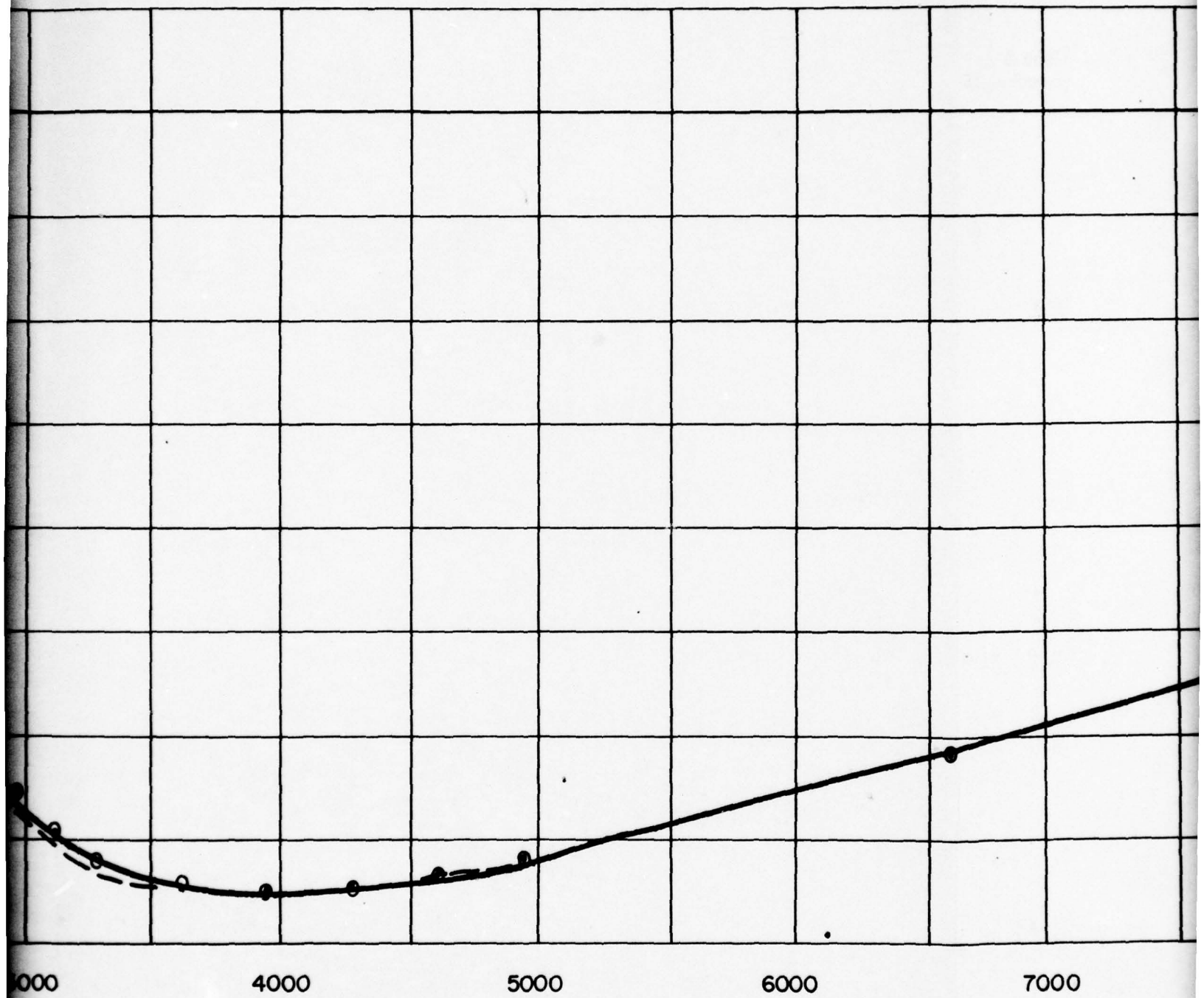
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TABLE 2

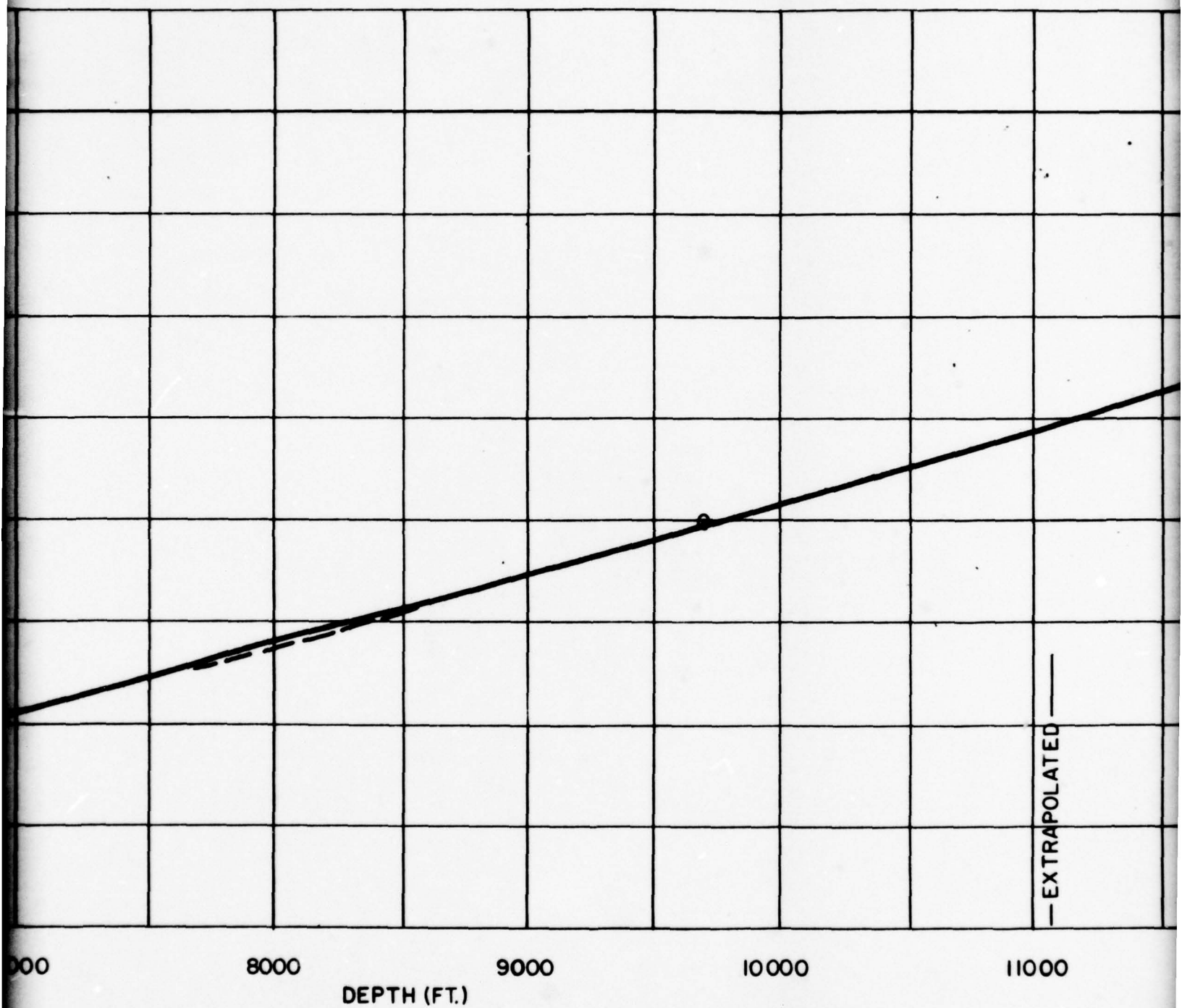
TIME REQUIREMENTS

<u>CAST</u>	<u>TIME (MINUTES)</u>
Nansen 1	170
Nansen 2	233
Nansen 3	286
Average Nansen Time	230
Profile 1-1	100
Profile 1-2	80
Profile 1-3	80
Profile 1-4	83
Profile 2-1	127
Profile 2-2	105
Profile 3-1	105
Profile 3-2	95
Profile 3-3	80
Average Profiling Time	95





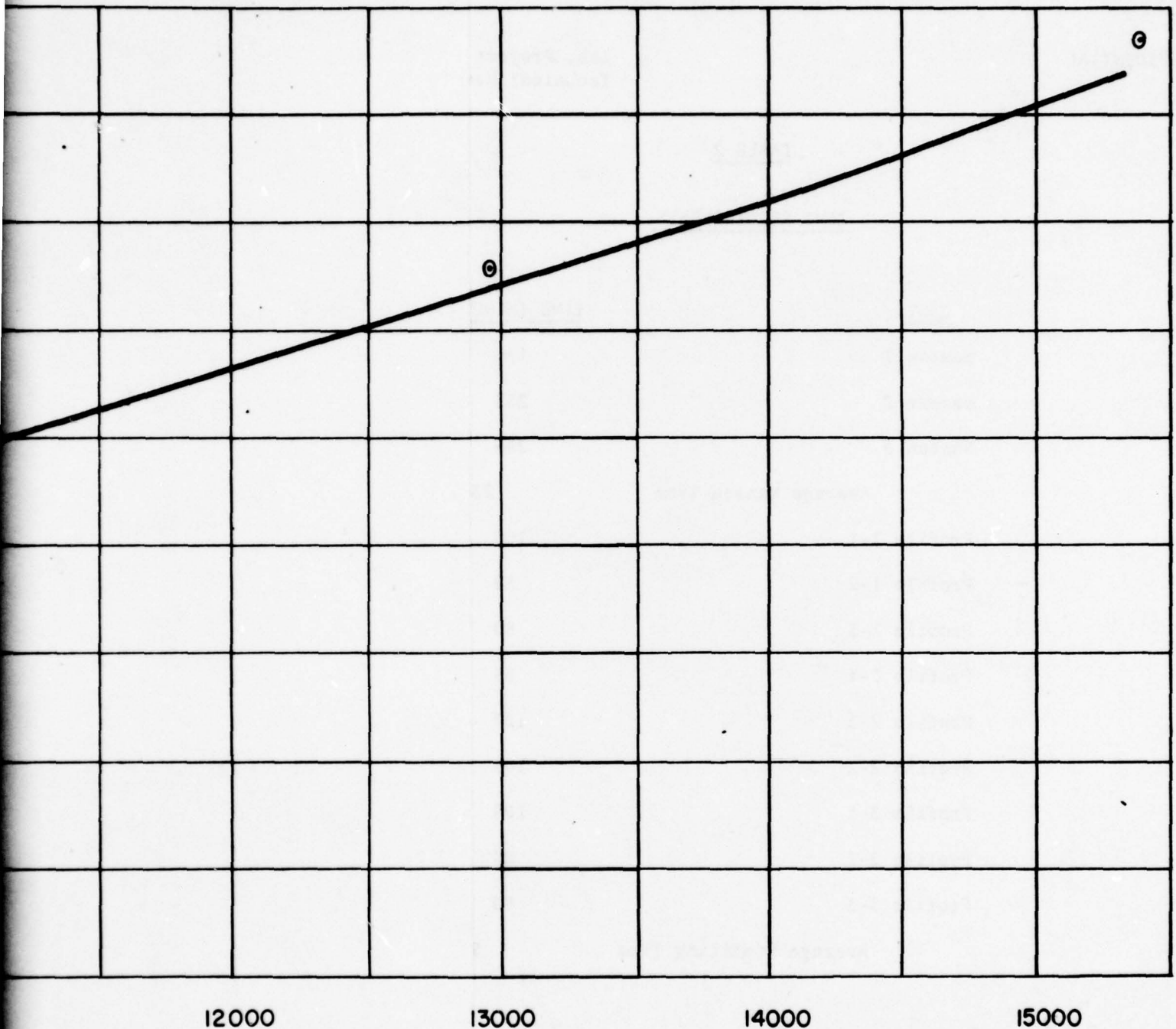
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DESCENT ———  
ASCENT - - - - -  
NANSEN CAST ○

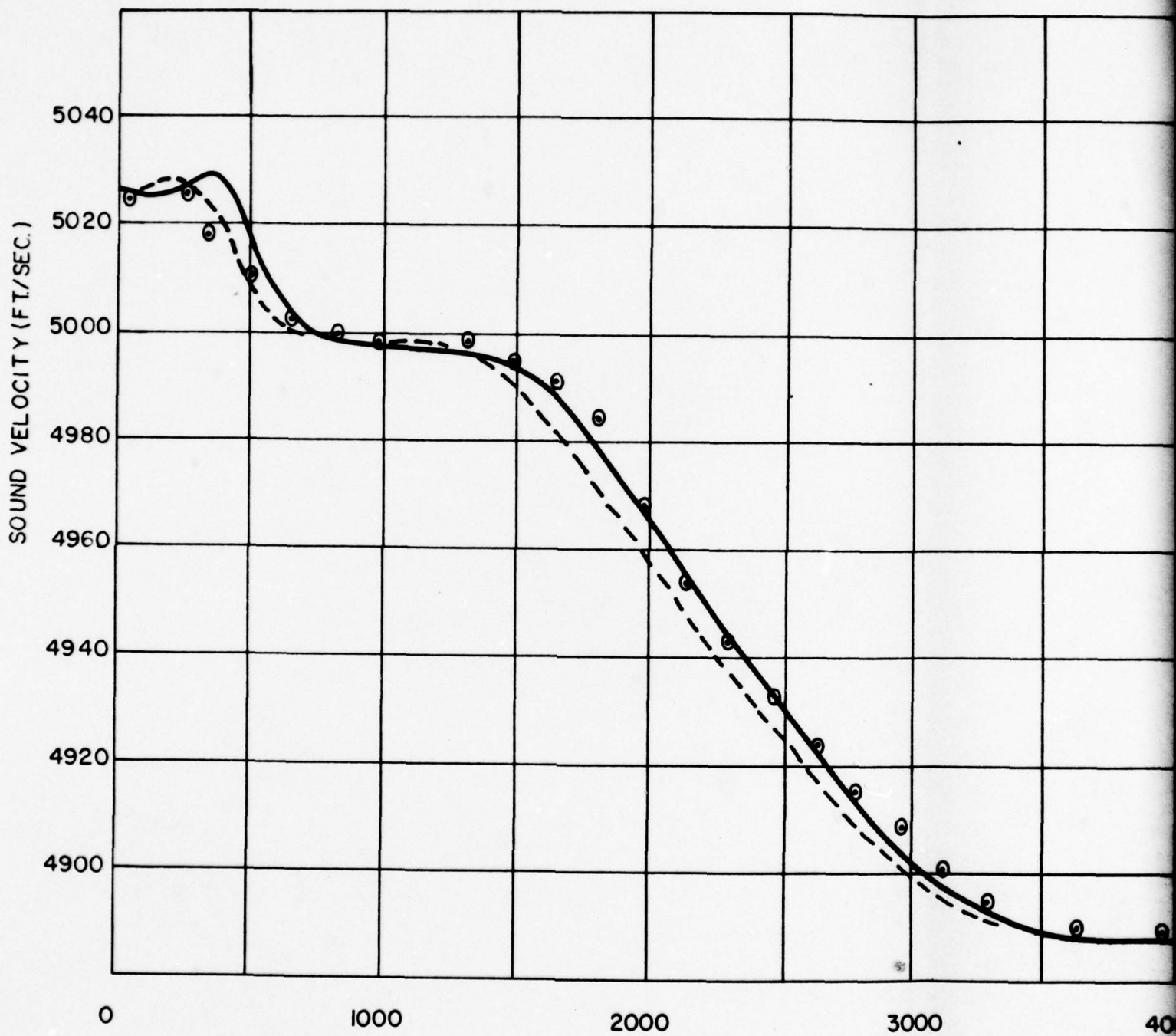
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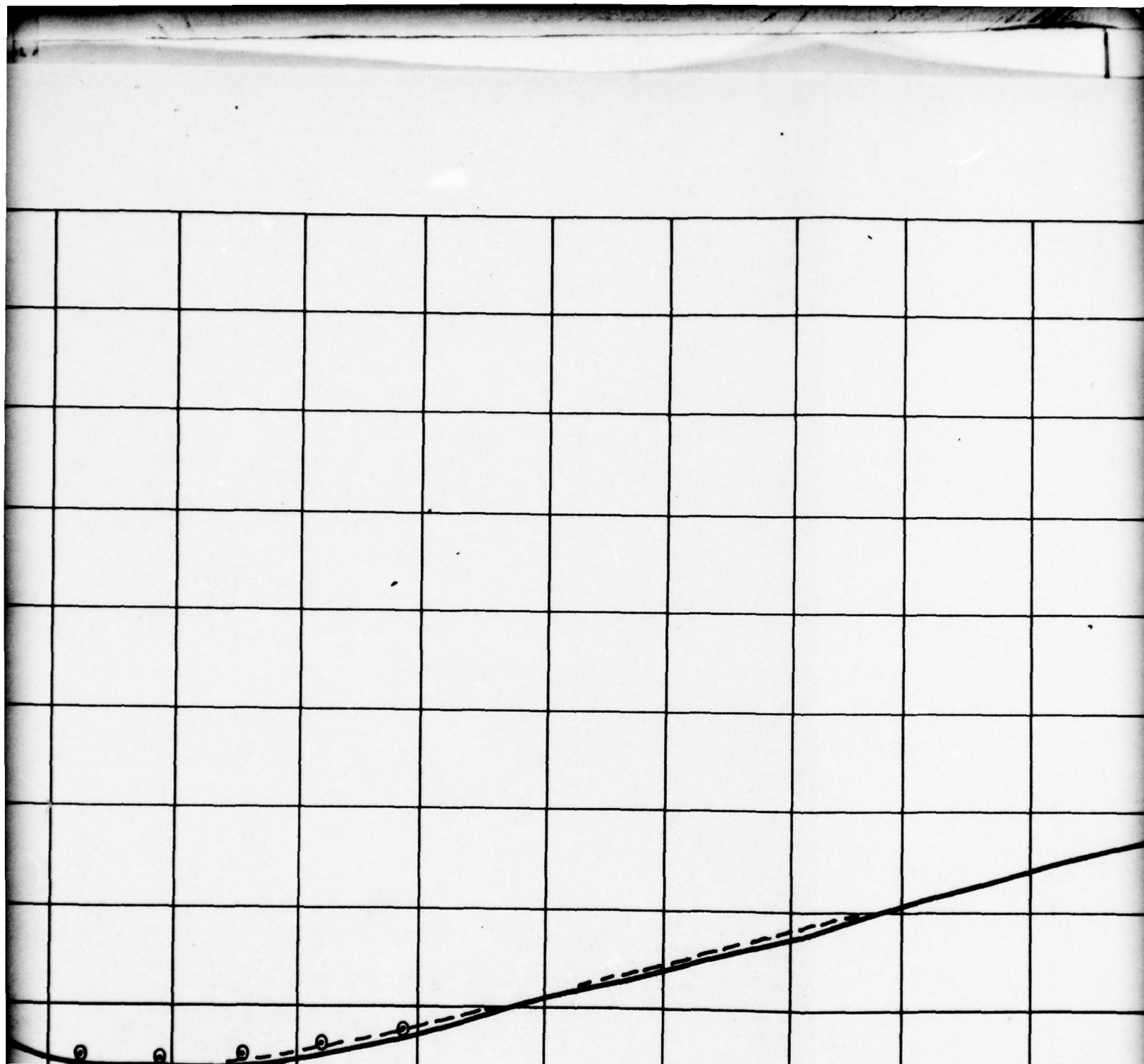
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SOUND VELOCITY PROFILE I-1, MODE A  
FIG. NO. 1 PG. NO. 13

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8000

9000

10 000

11000

12000

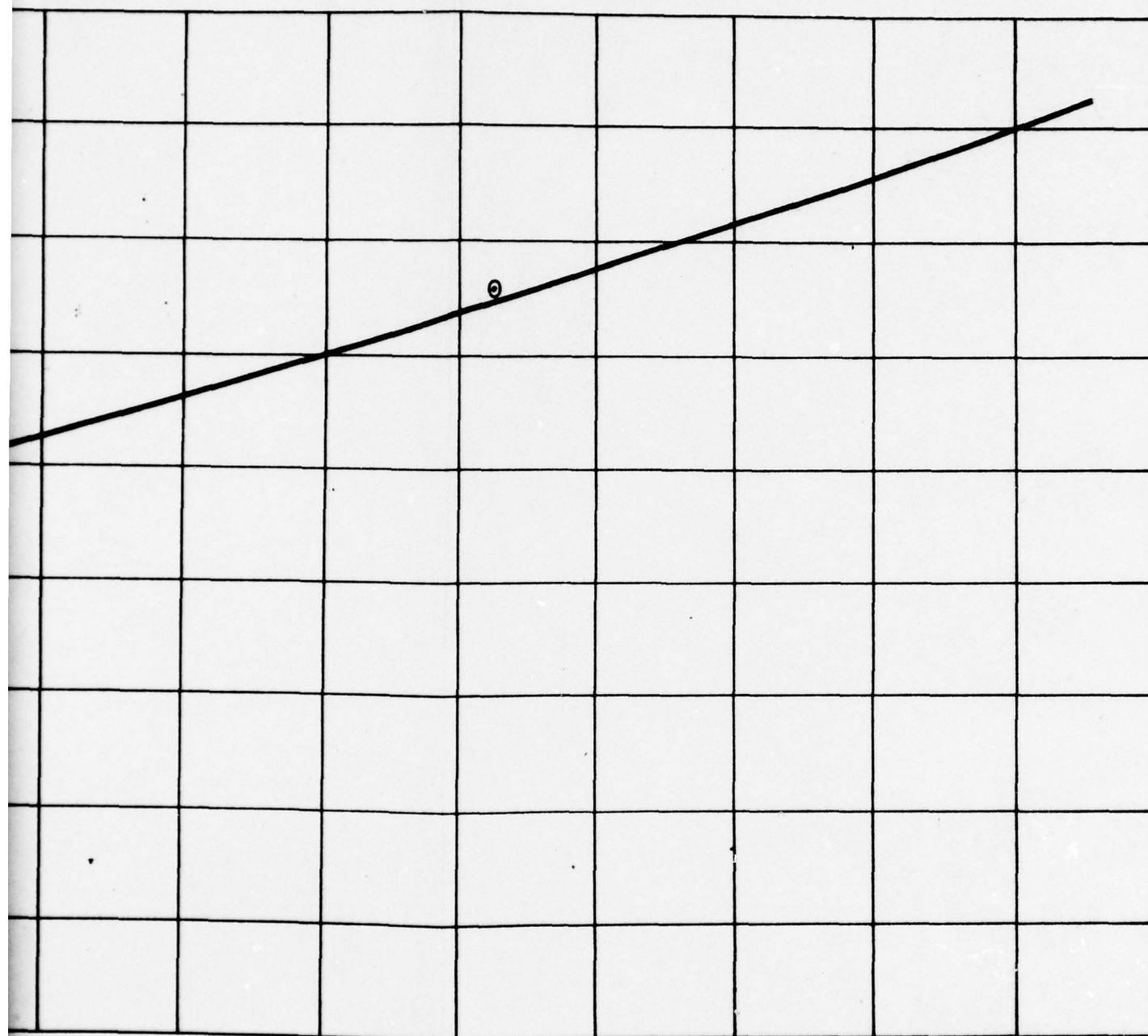
DEPTH (FT.)

DESCENT ———

ASCENT - - - - -

NANSEN CAST 0

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12000

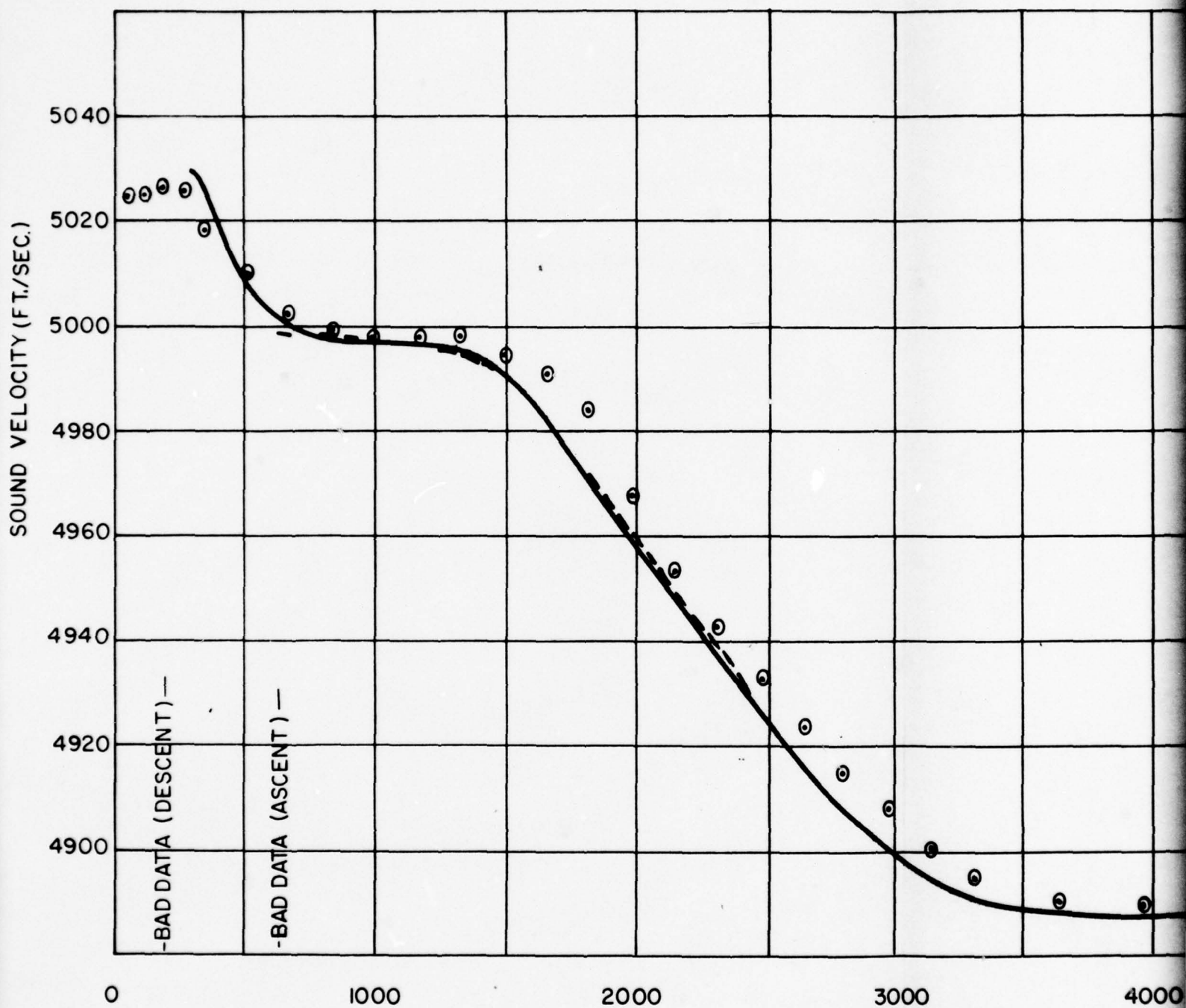
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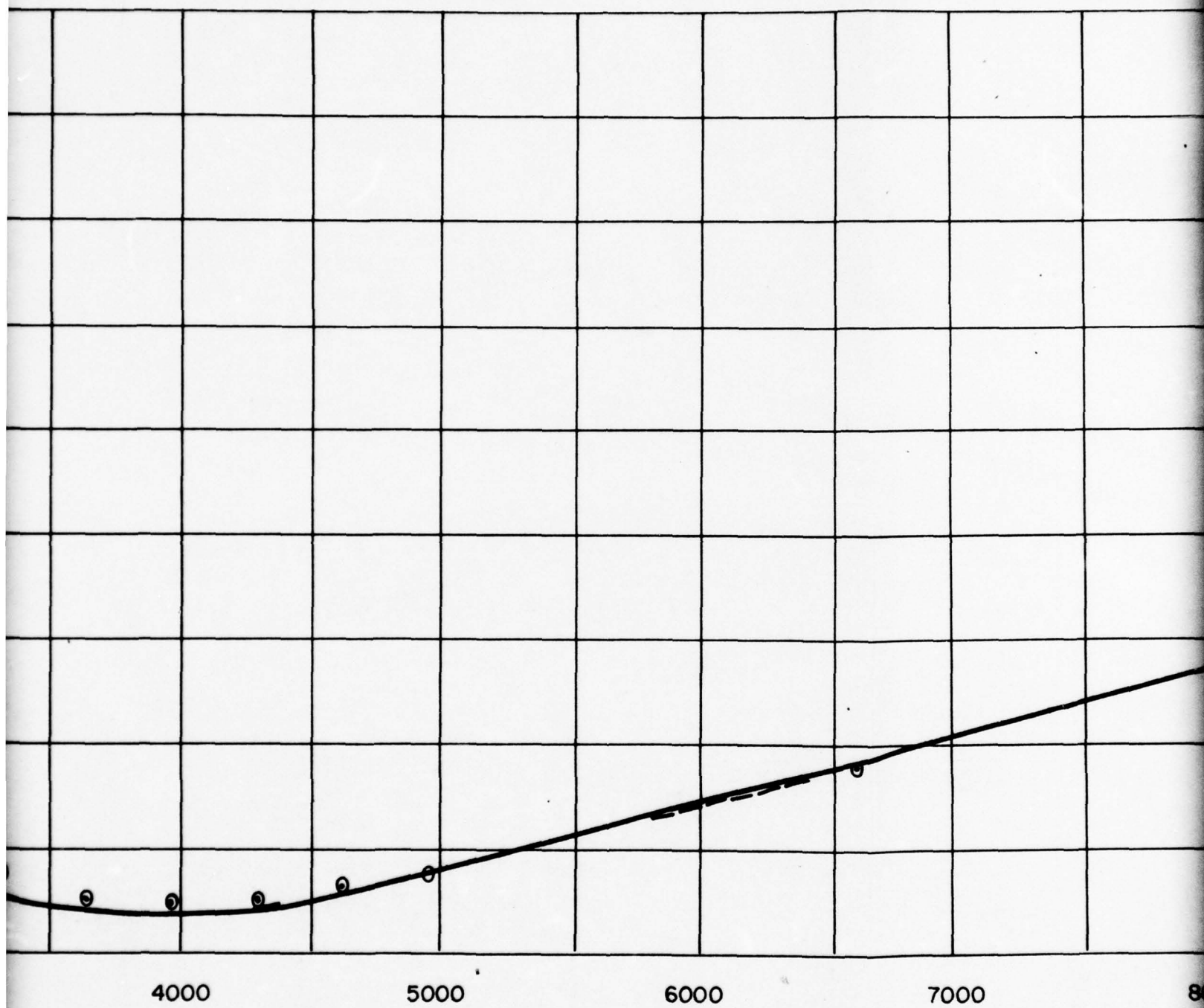
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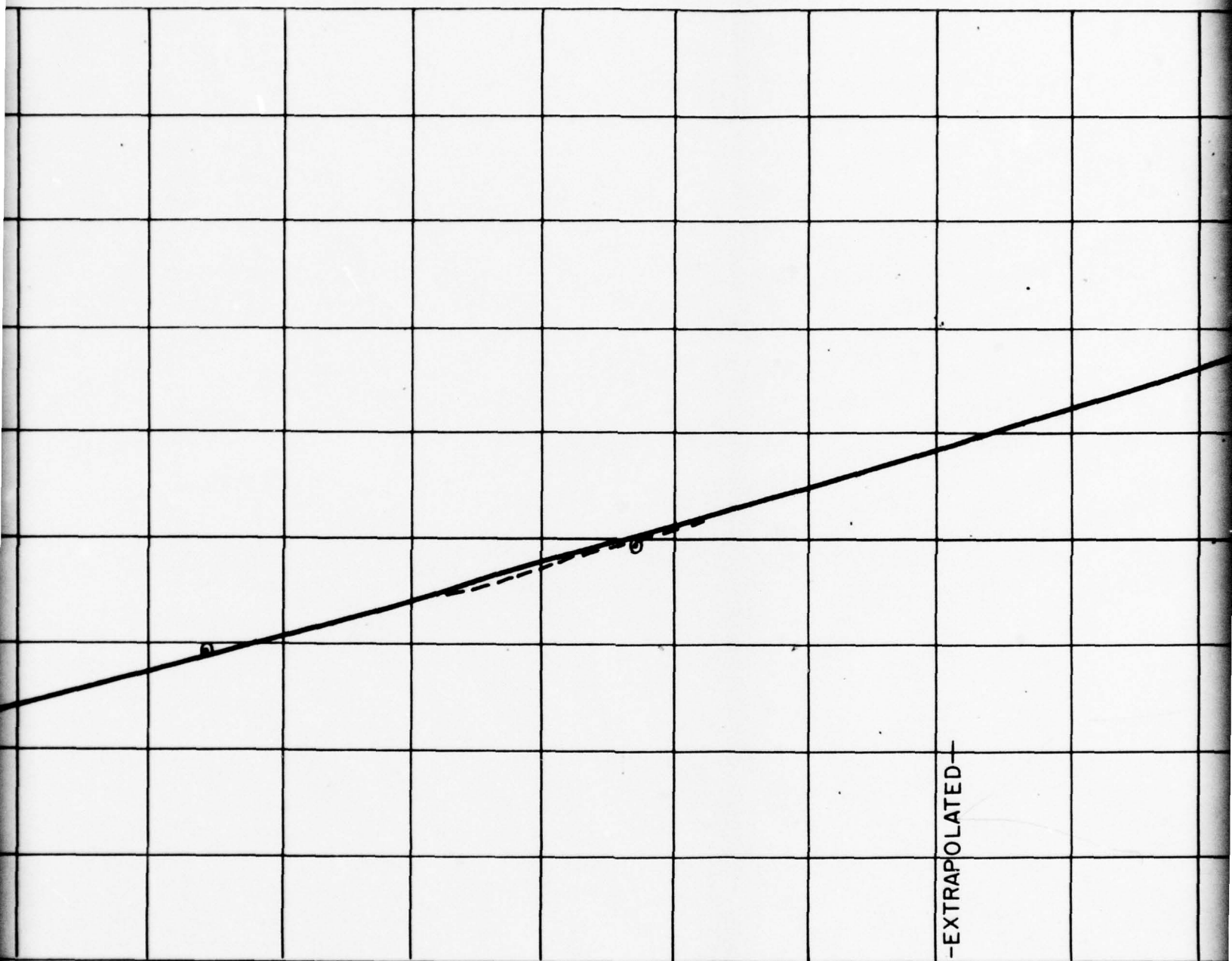
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TECHNICAL MEMORANDUM NO.15  
SOUND VELOCITY PROFILE i-2, MODE B  
FIG. NO. 2 PG. NO. 14

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2



8000

DEPTH (FT.)

9000

10000

11000

12000

DESCENT ———

ASCENT - - - - -

NANSEN CAST O

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12000

13000

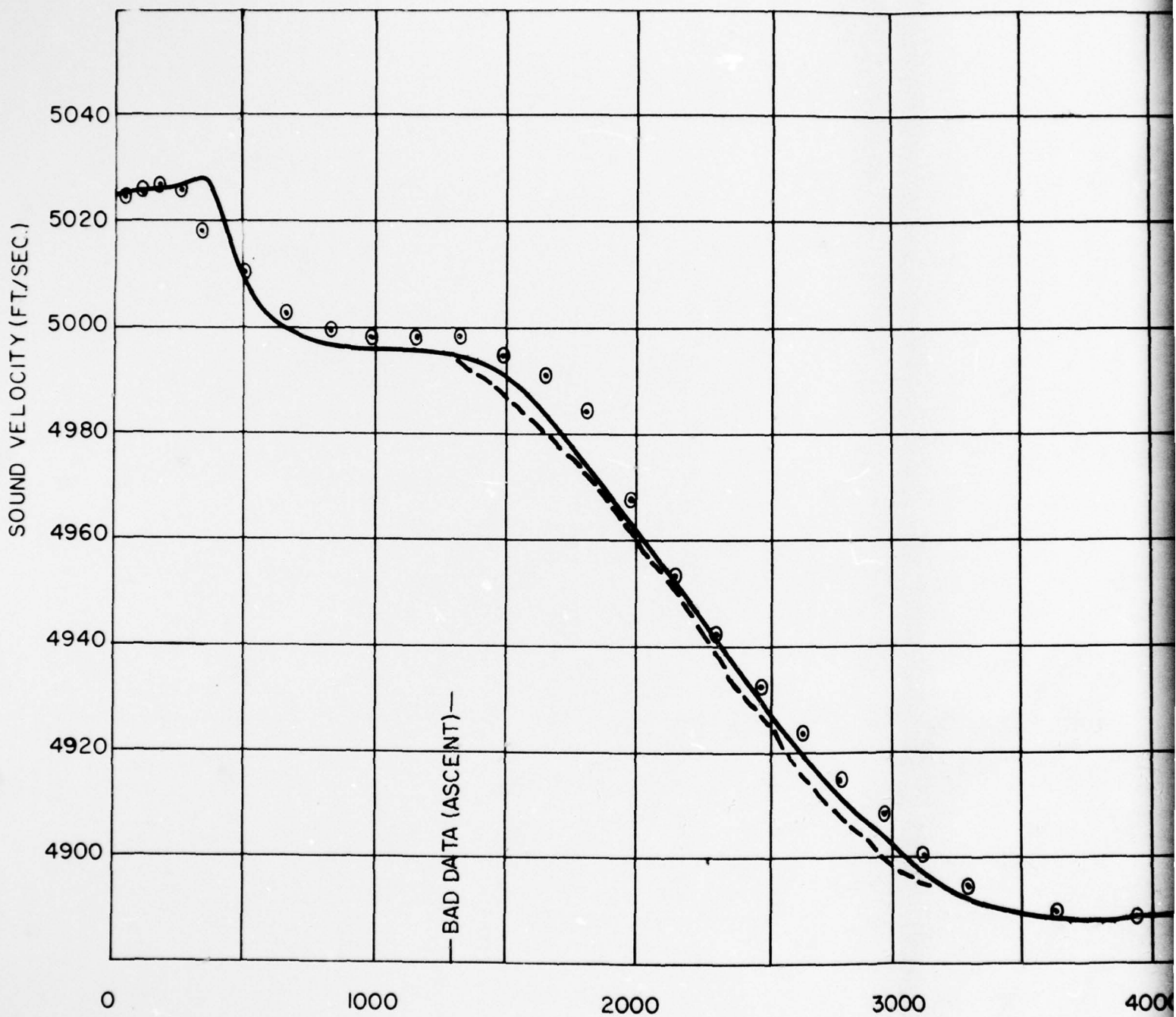
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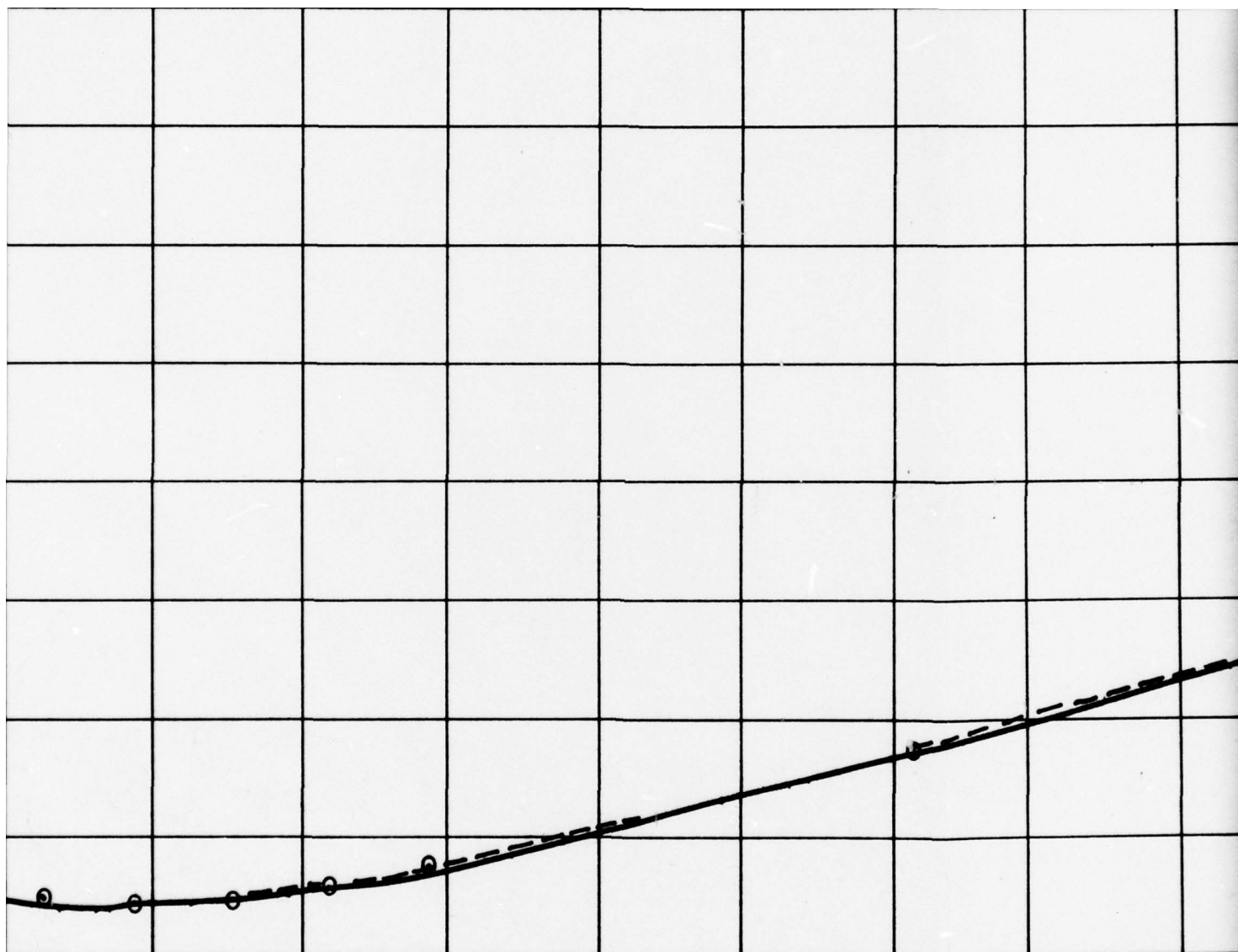
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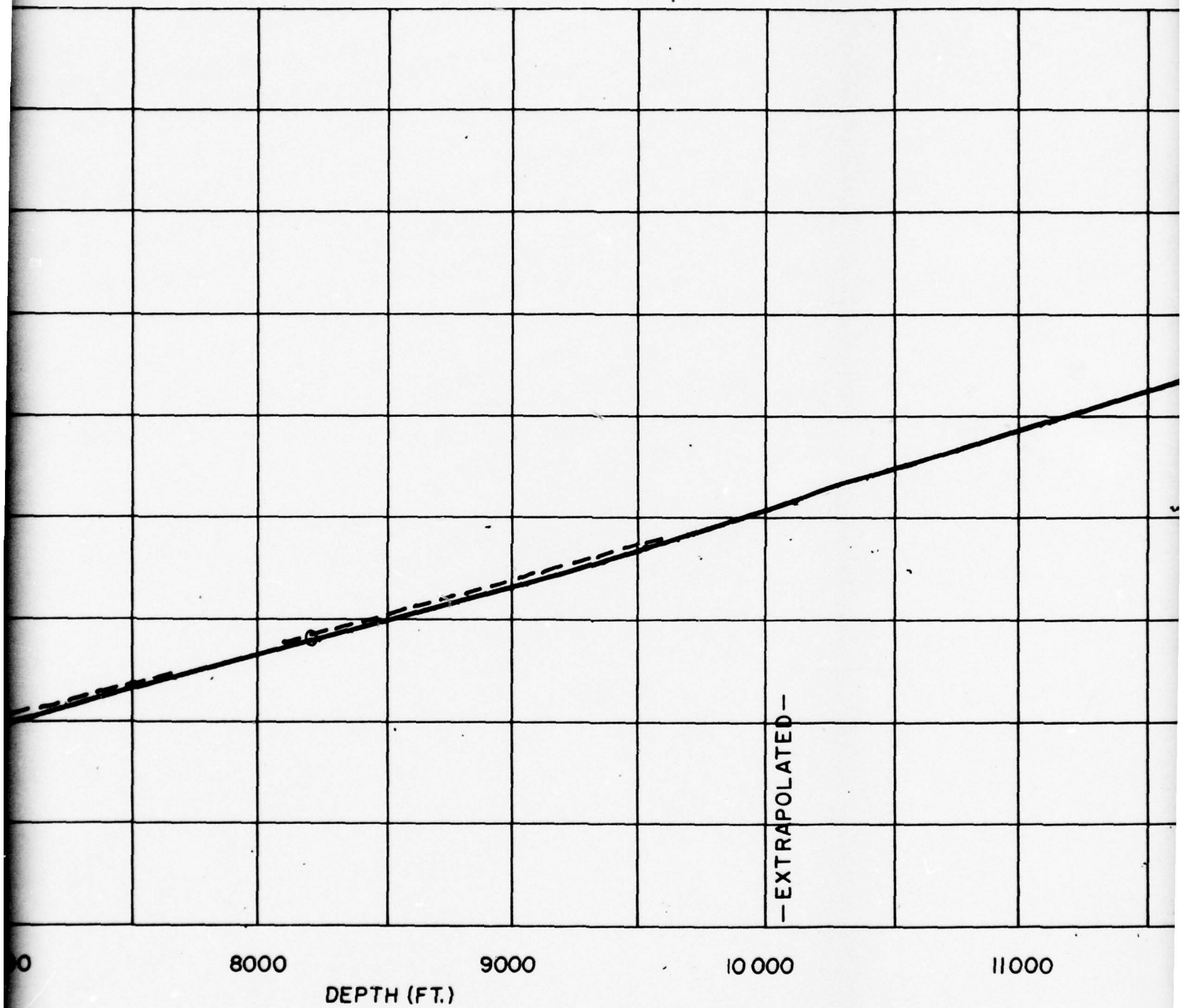
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TECHNICAL MEMORANDUM NO. 15  
SOUND VELOCITY PROFILE 1-3, MODE C  
FIG. NO. 3 PG. NO. 15

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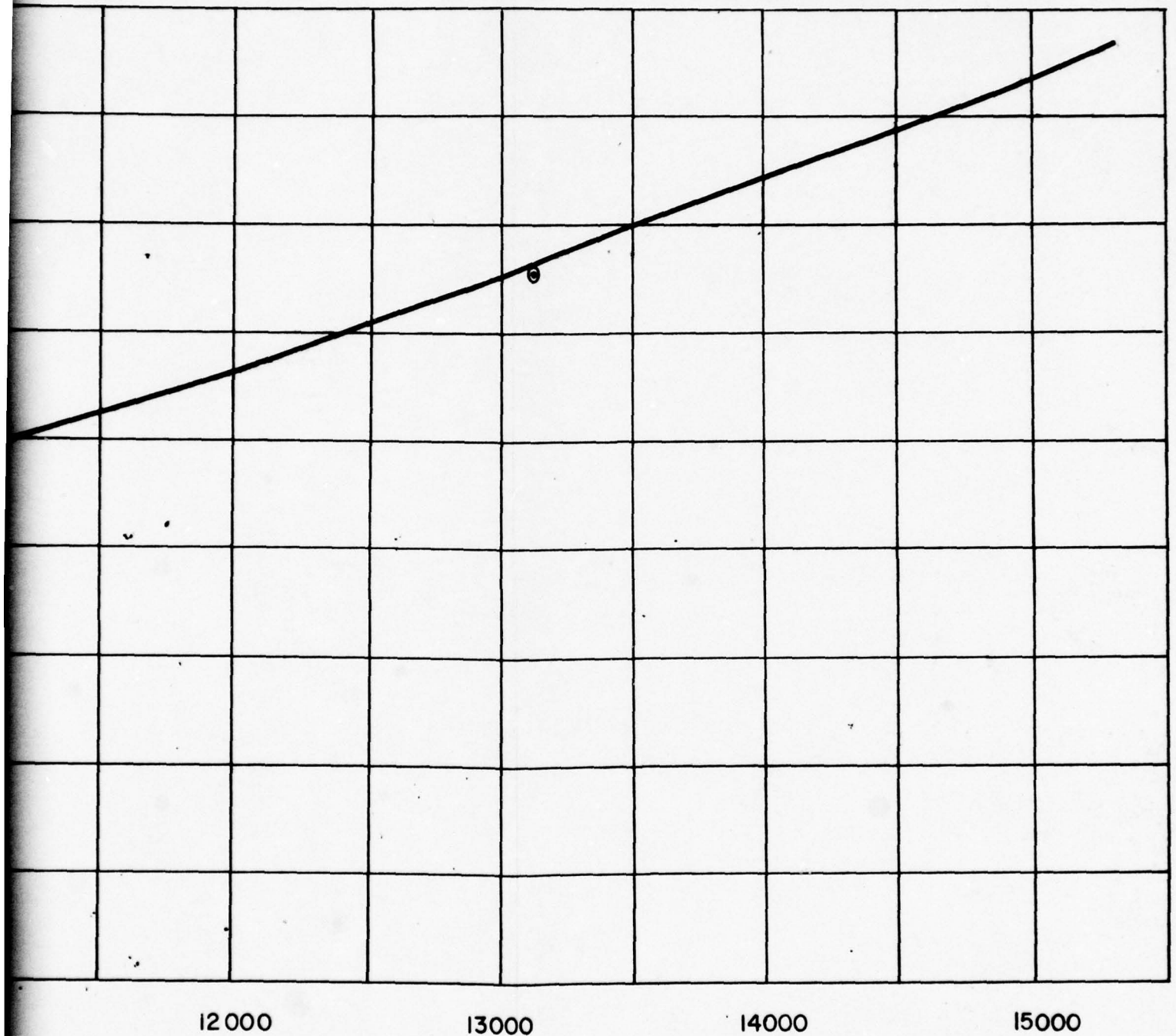






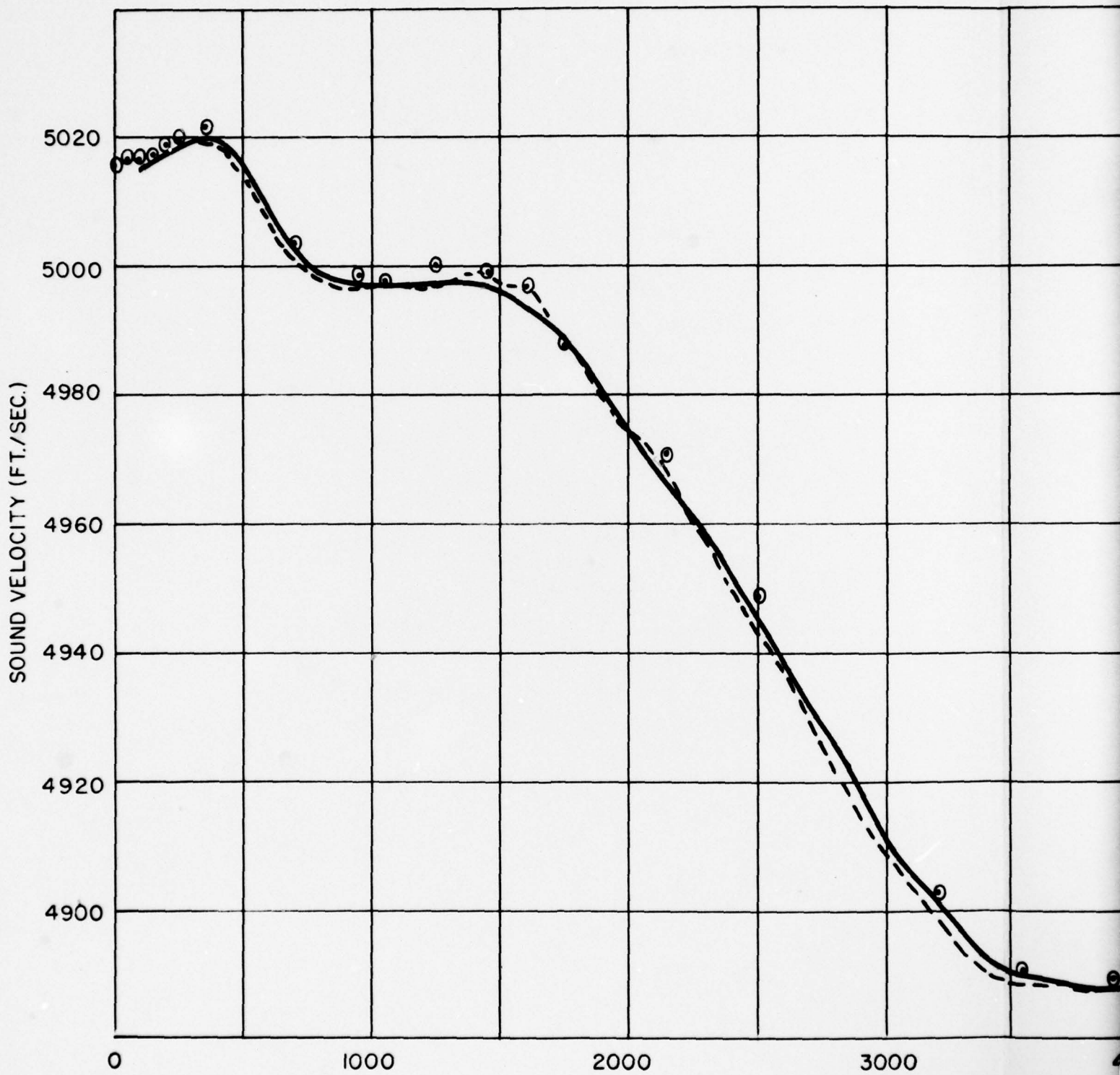
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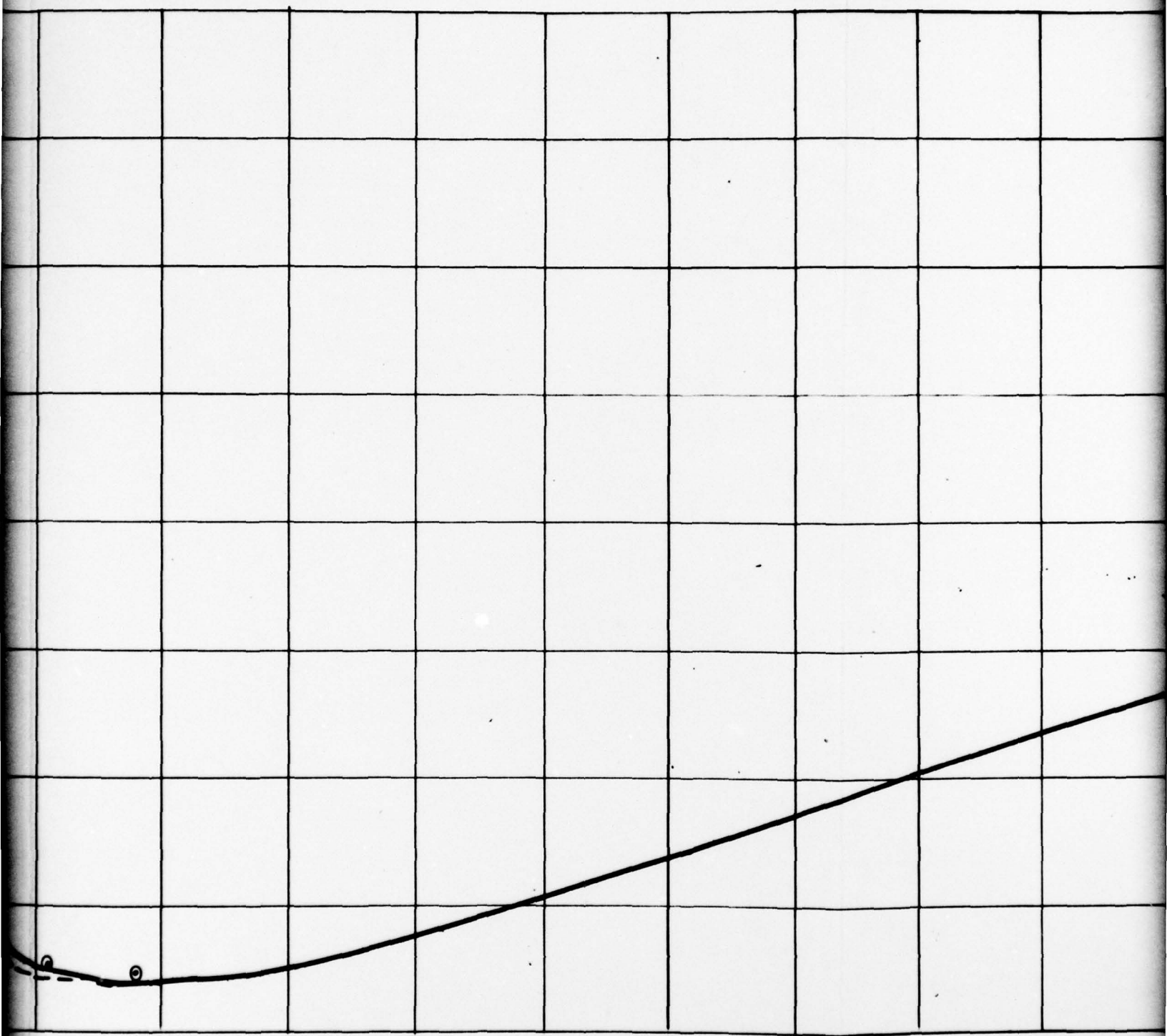


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TECHNICAL MEMORANDUM NO. 15  
SOUND VELOCITY PROFILE 1-4, MODE A  
FIG. NO. 4 PG. NO. 16

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CO



4000

5000

6000

7000

8000

DEPTH(FT.)

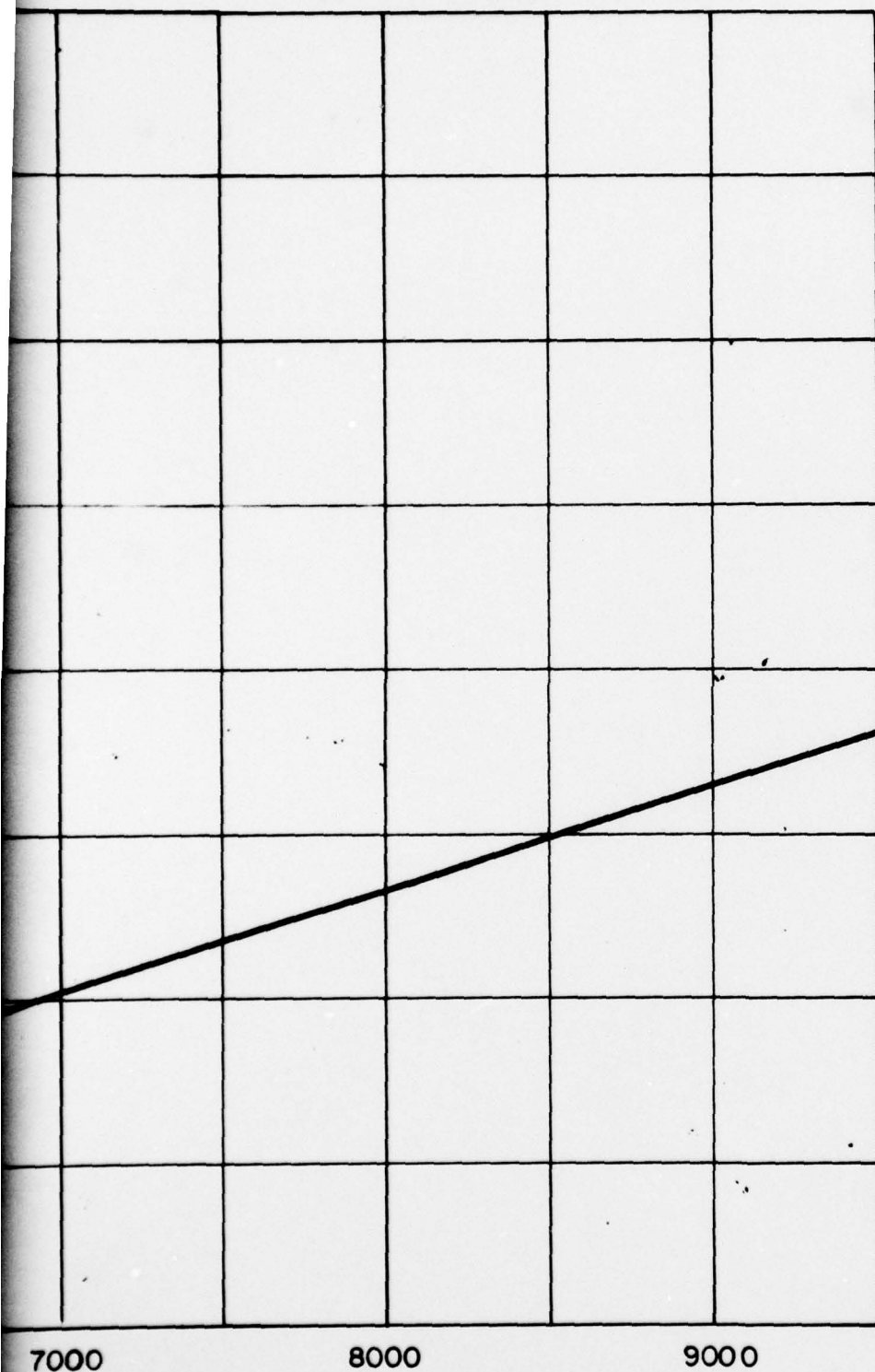
DESCENT ———  
ASCENT - - - - -  
NANSEN CAST 0

2

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LABORATORY  
TECHNICAL  
SOUNDING  
FIG. 1

CO

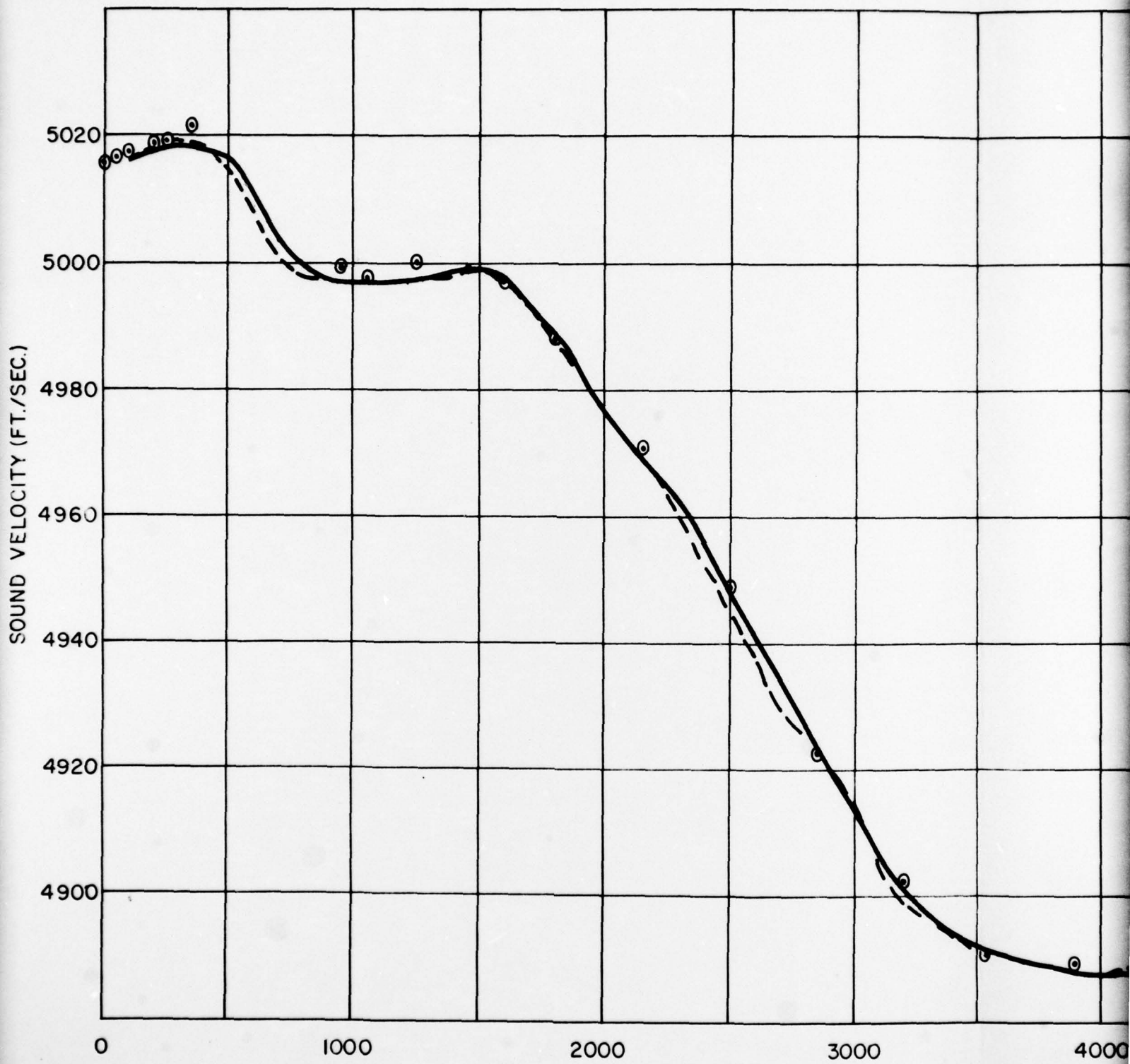
**CONFIDENTIAL**

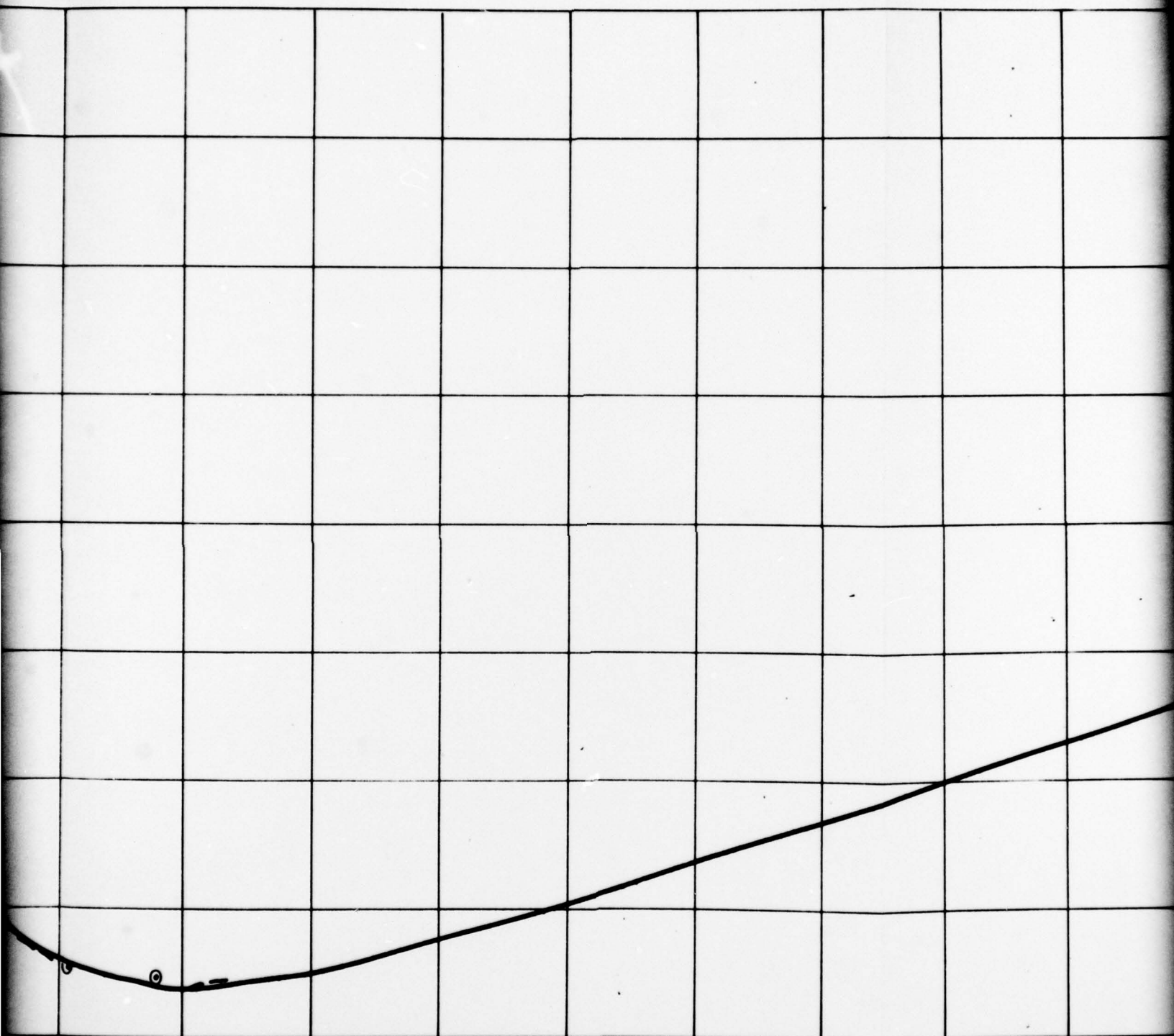


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SOUND VELOCITY PROFILE 2-1  
FIG.NO. 5 PG.NO. 17

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3





4000

DEPTH (FT)

5000

6000

7000

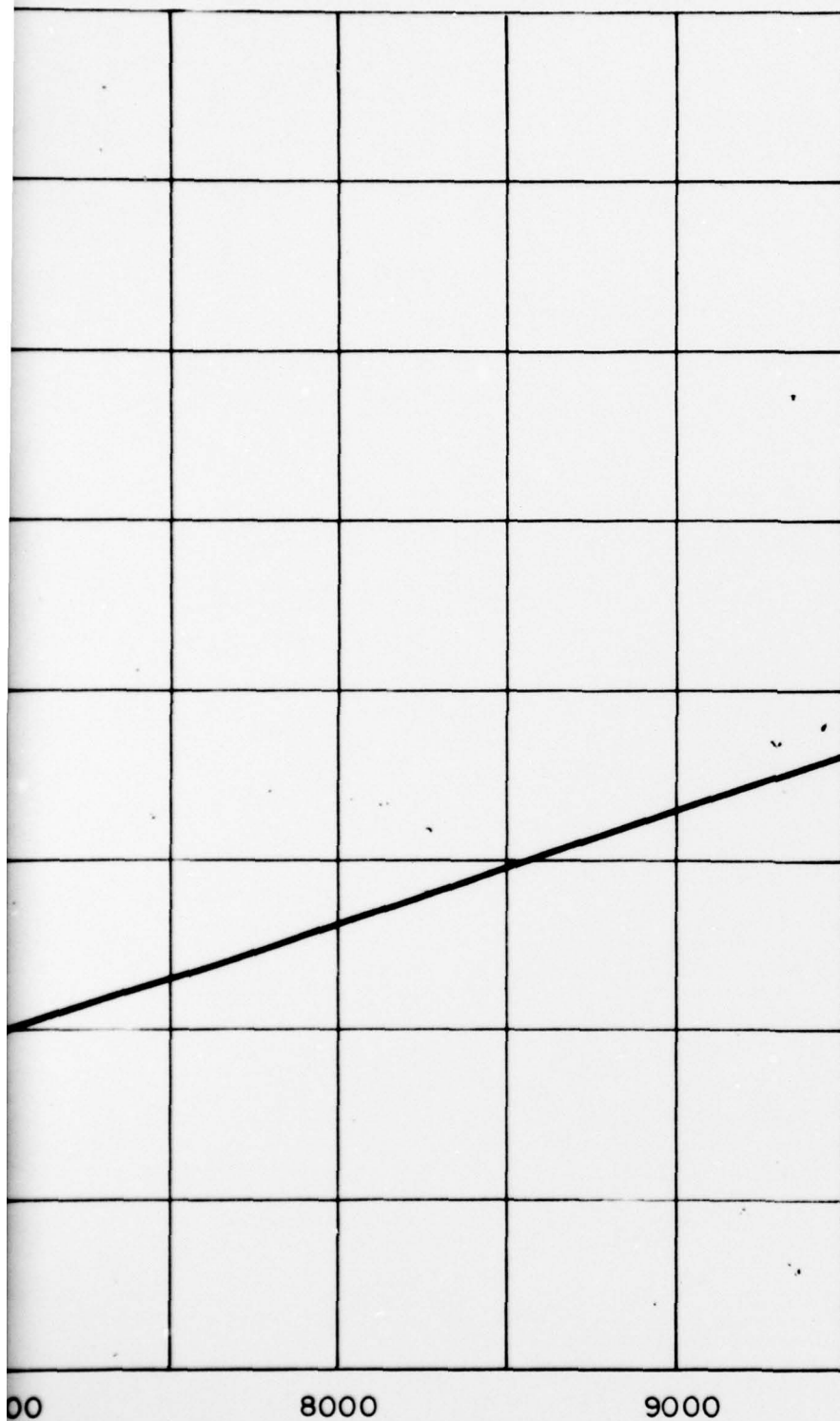
DESCENT ———

ASCENT - - - - -

NANSEN CAST ①

2

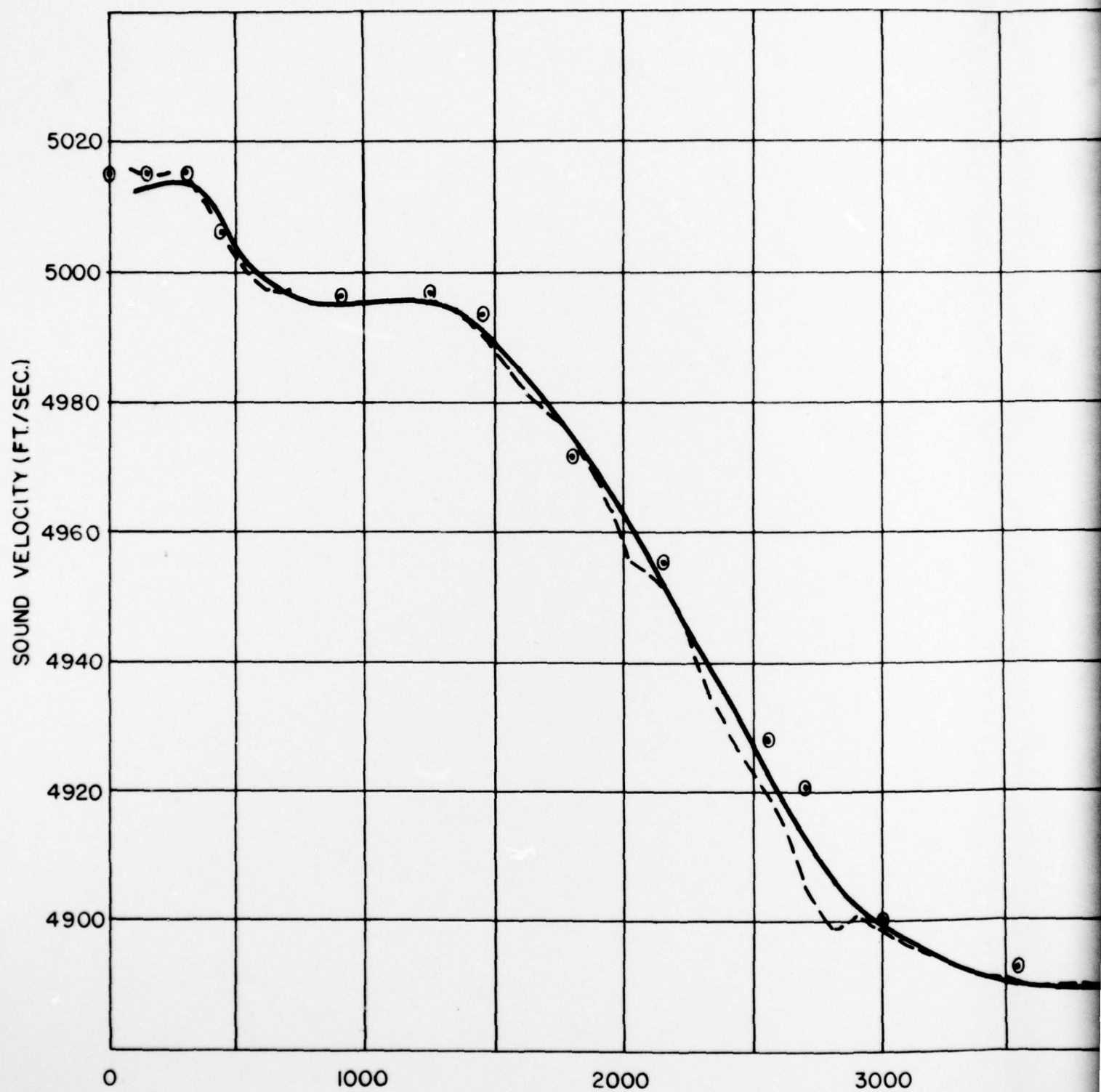
**CONFIDENTIAL**

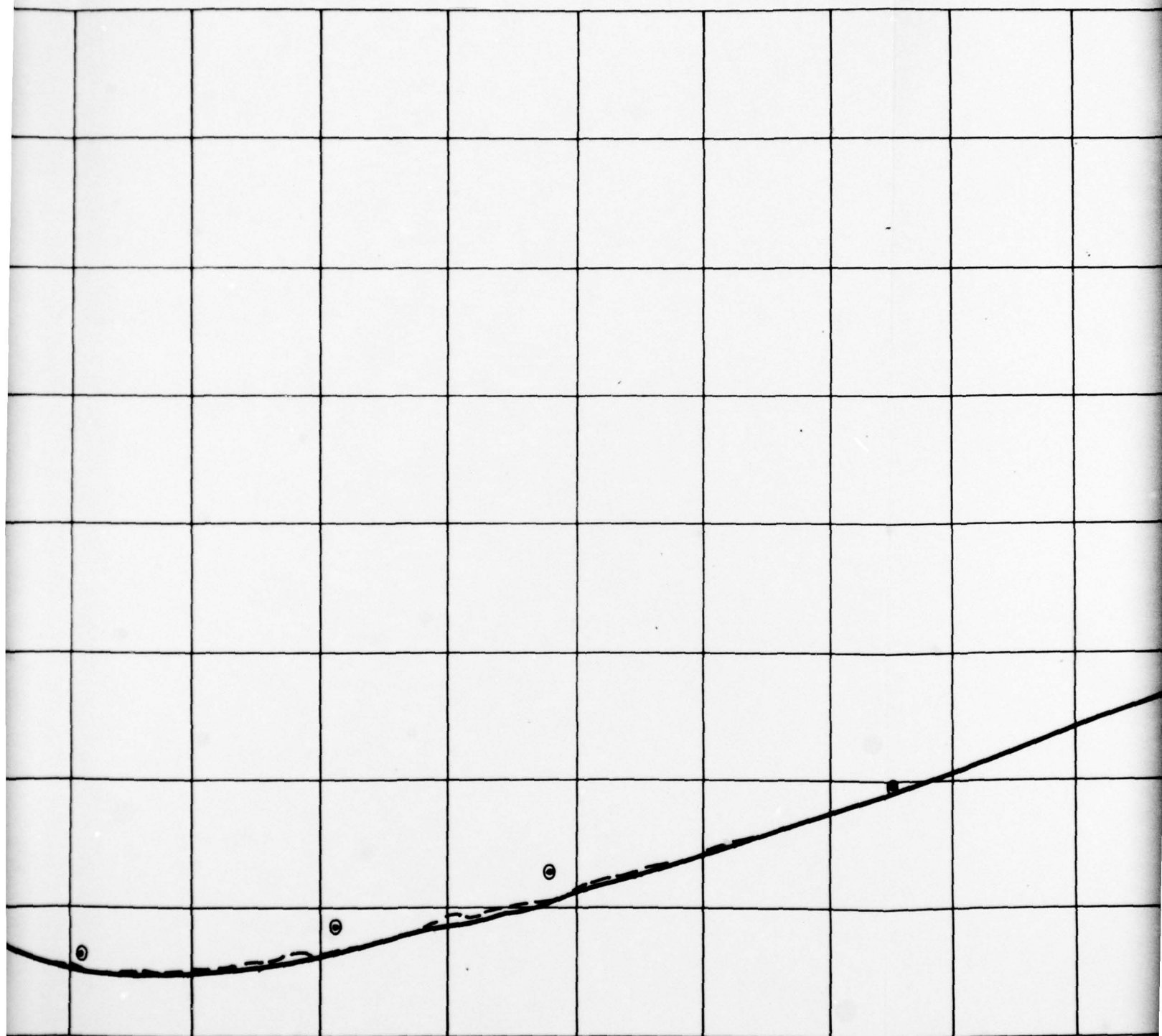


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SOUND VELOCITY PROFILE 2-2  
FIG. NO. 6 PG. NO.18

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3





4000

DEPTH(FT.)

5000

6000

7000

DESCENT ———

ASCENT - - - -

NANSEN CAST ○

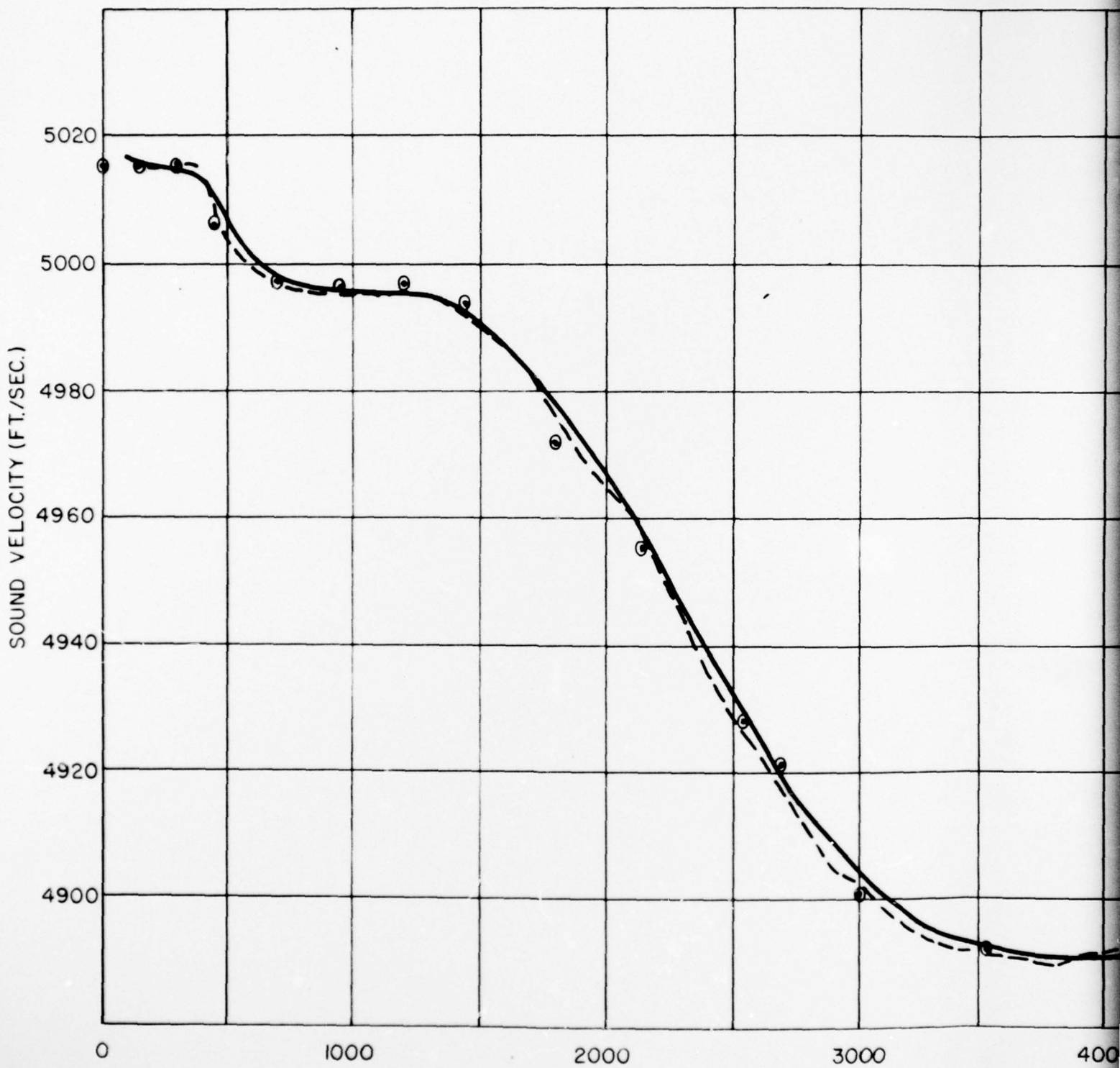
2

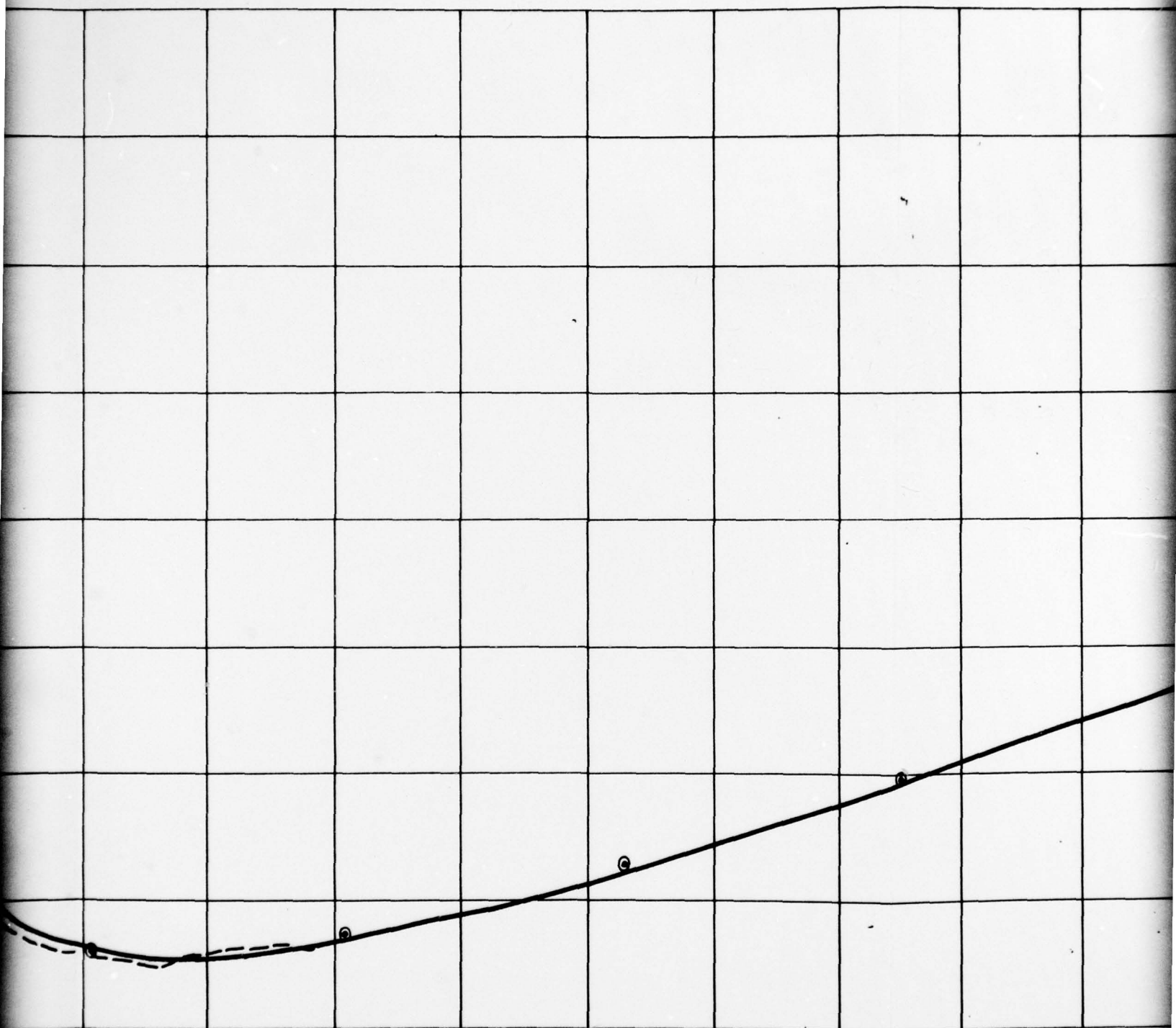
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TECHNICAL MEMORANDUM NO. 15  
SOUND VELOCITY PROFILE 3-1  
FIG. NO. 7 PG. NO. 19

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4000

DEPTH (FT.)

5000

6000

7000

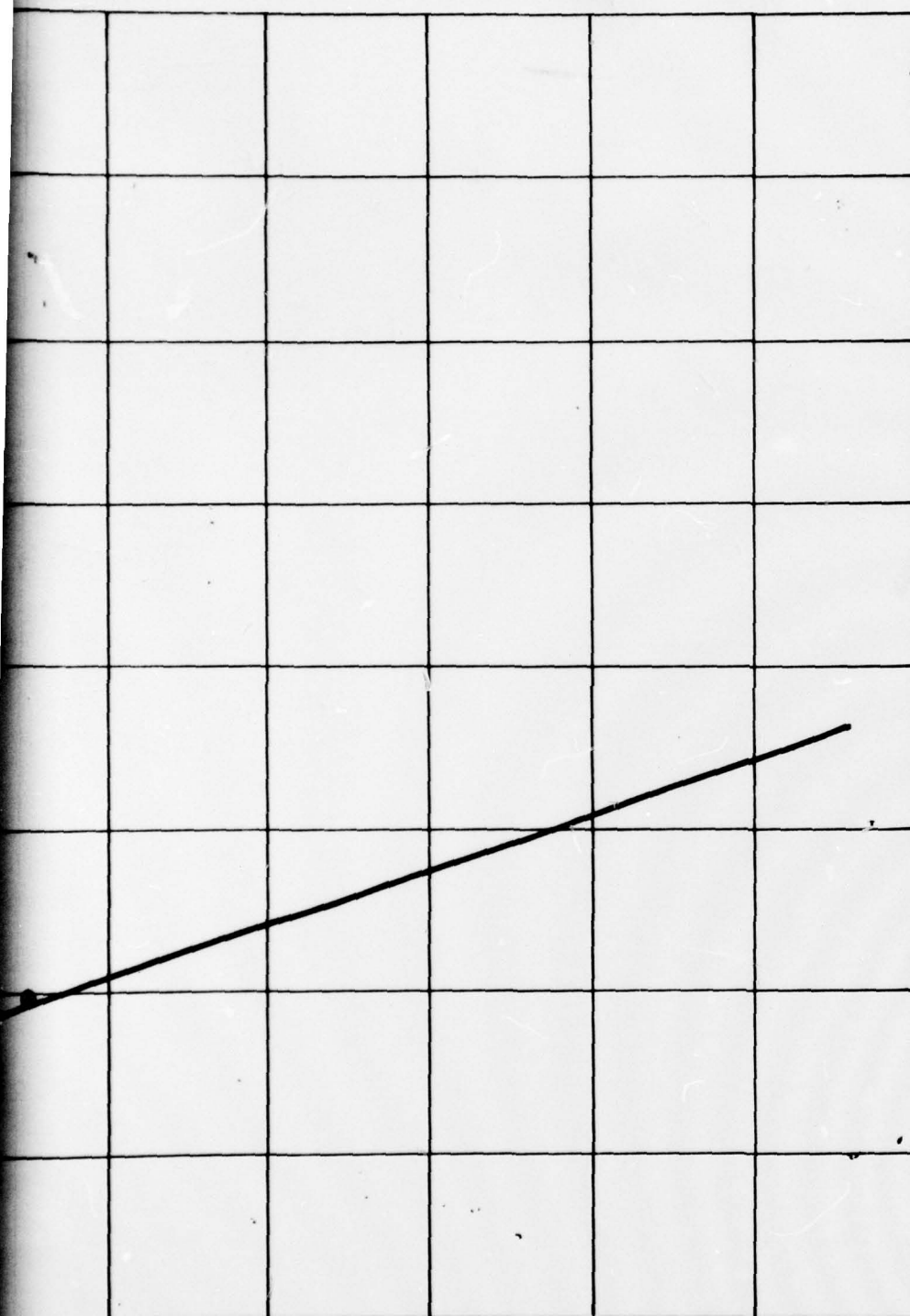
DESCENT ———

ASCENT - - - - -

NANSEN CAST ○

2

CONFIDENTIAL



7000

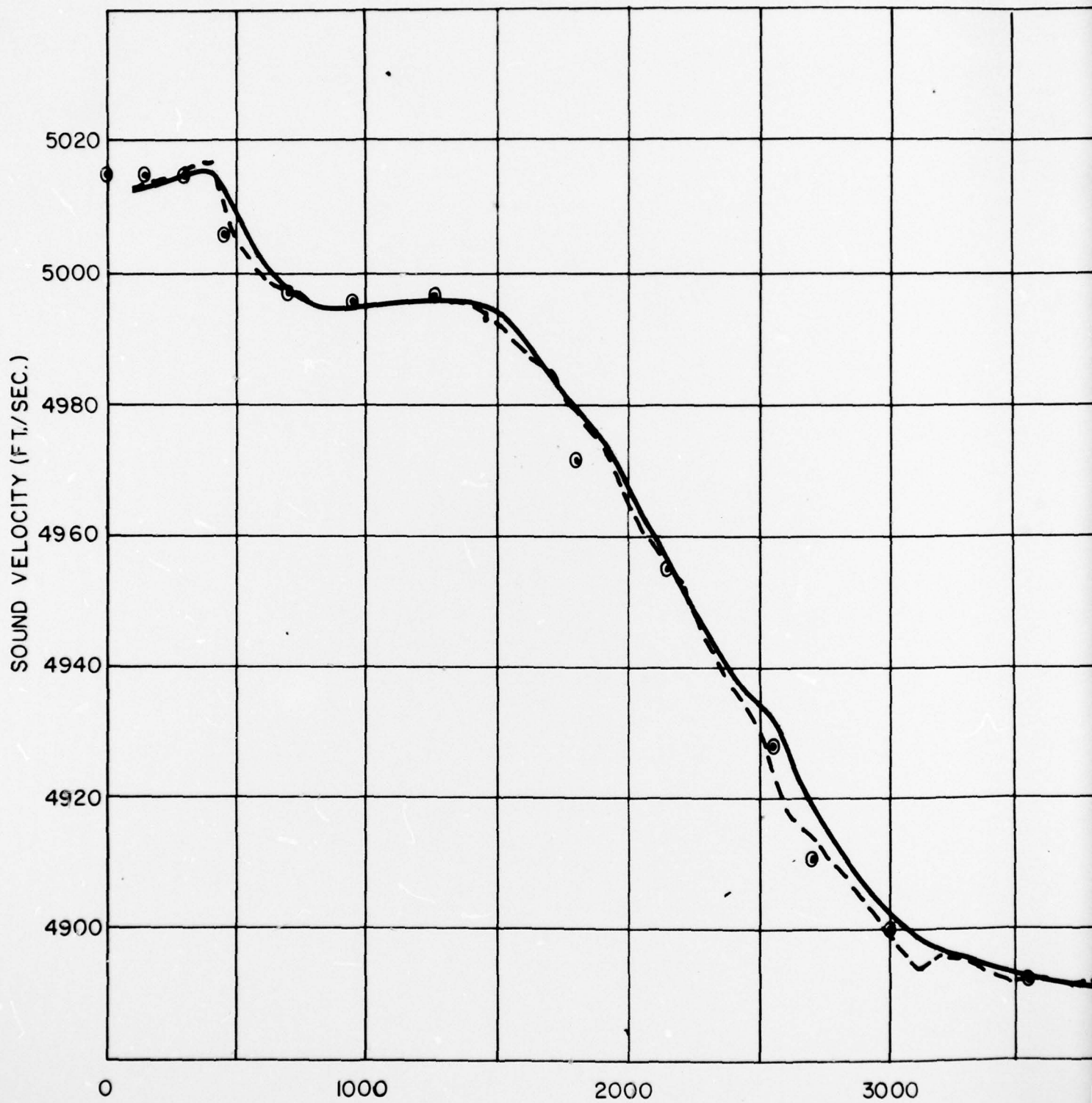
8000

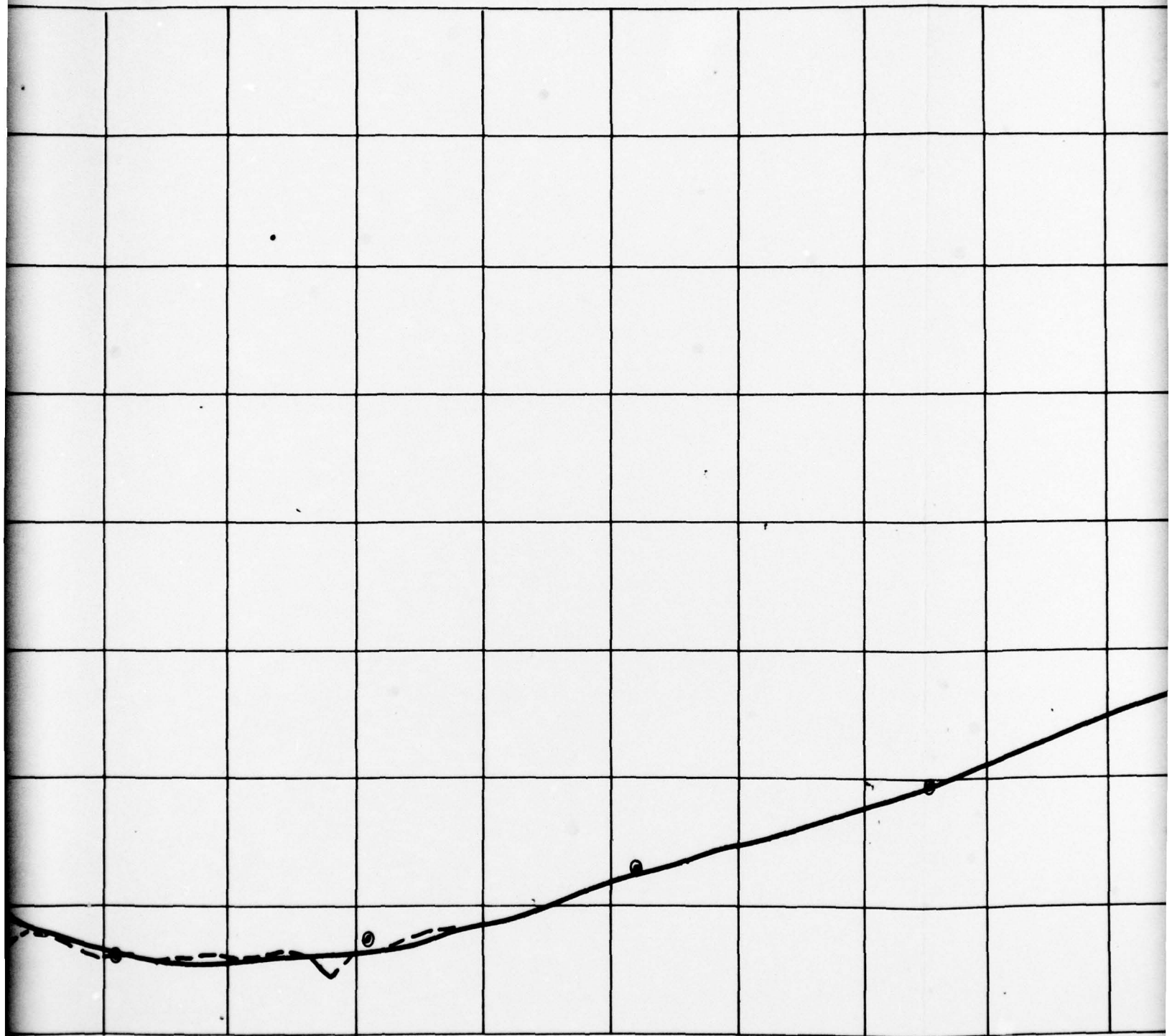
9000

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TECHNICAL MEMORANDUM NO. 15  
SOUND VELOCITY PROFILE 3-2  
FIG. NO. 8 PG. NO. 20

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3





4000

DEPTH (FT.)

5000

6000

7000

DESCENT ———

ASCENT - - - -

NANSEN CAST 0

2

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TECHNICAL MEMORANDUM NO. 15  
SOUND VELOCITY PROFILE 3-3  
FIG. NO. 9 PG. NO. 2

3

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